



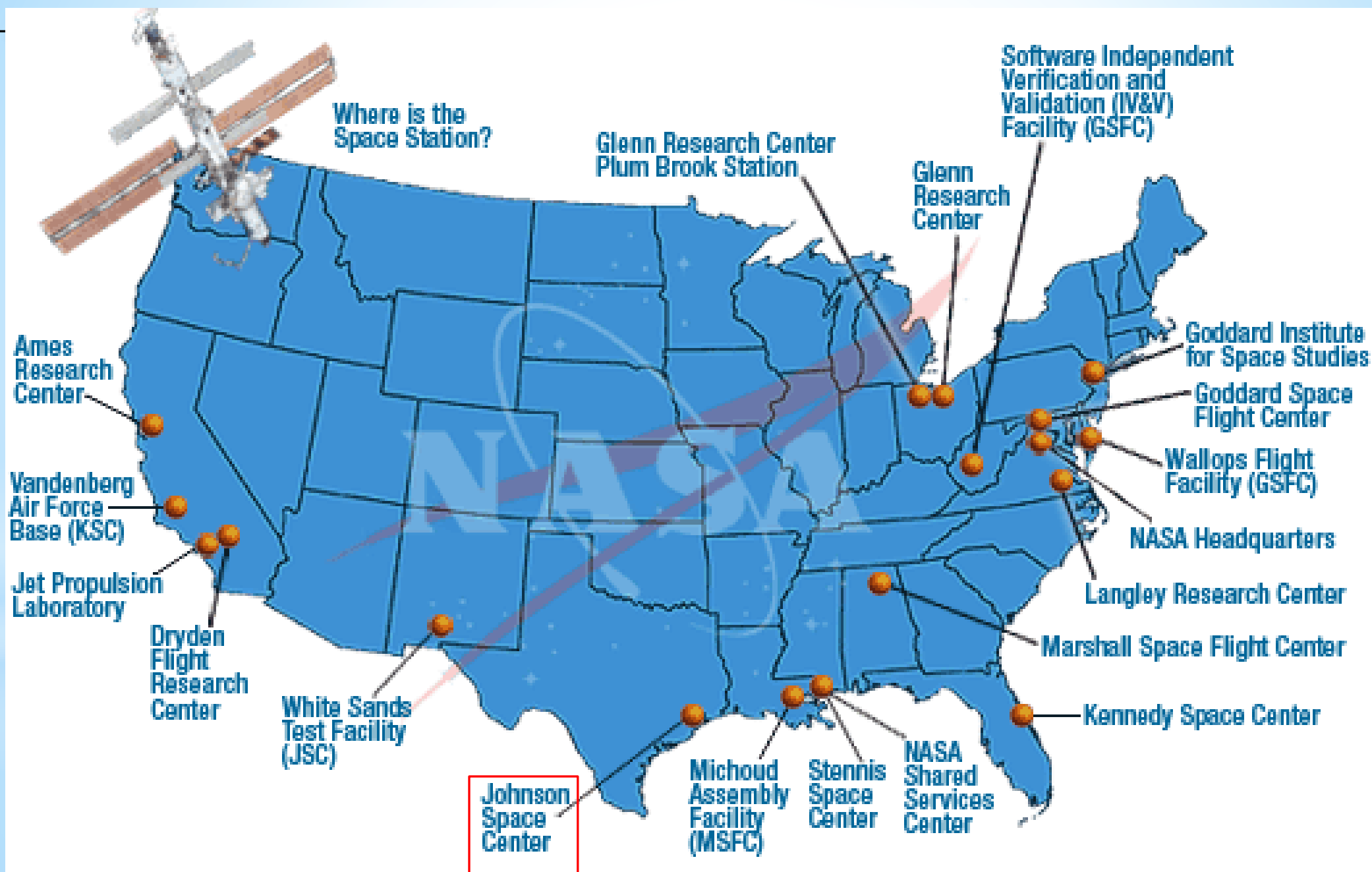
Space : A Promising Frontier

Antony Jeevarajan, Ph.D.
Johnson Space Center
National Aeronautics and Space Administration
Houston, TX 77058
Email: antony.s.jeevarajan@nasa.gov

- ❖ **Where are we in the Universe?**
- ❖ **Technology Evolution during Human Space Exploration Missions**
- ❖ **Mathematics : A Unifying Discipline**
- ❖ **More importantly, to answer your questions**



NASA Centers



Our Habitation at Night



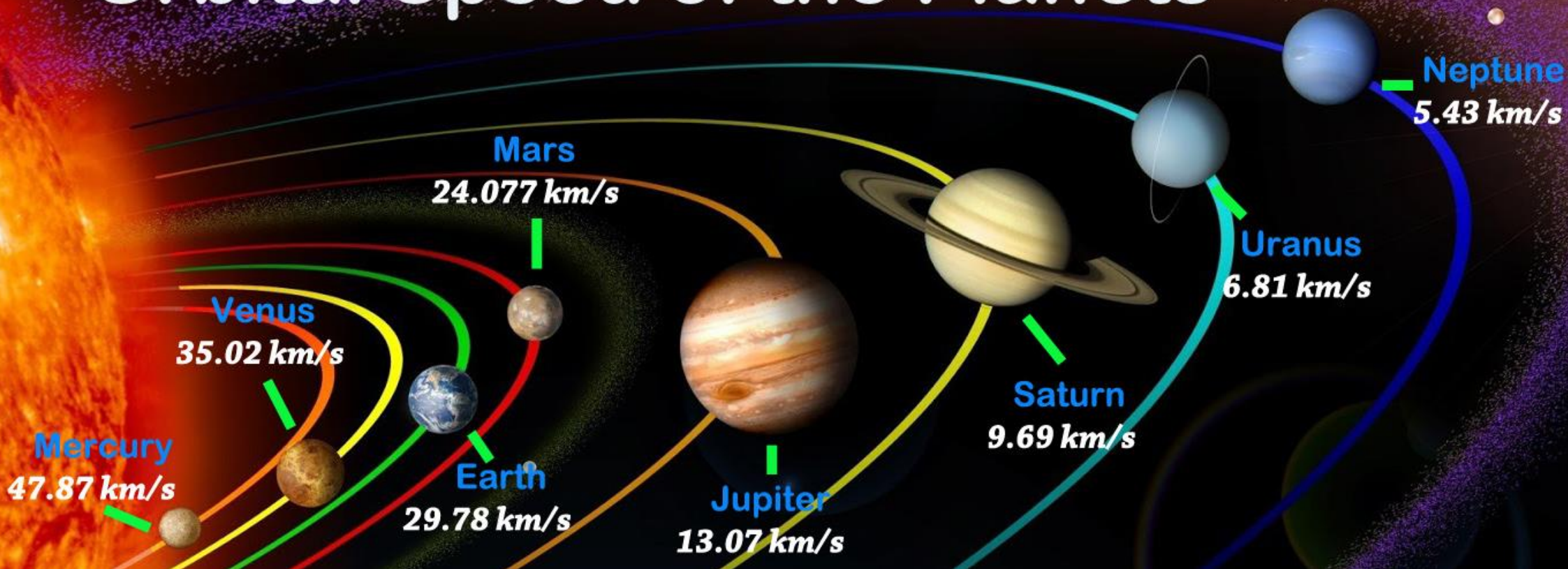
Beautiful Fragile Blue Planet (~400,000 km)



Mars - Earth Mutual View (~400,000,000 km)

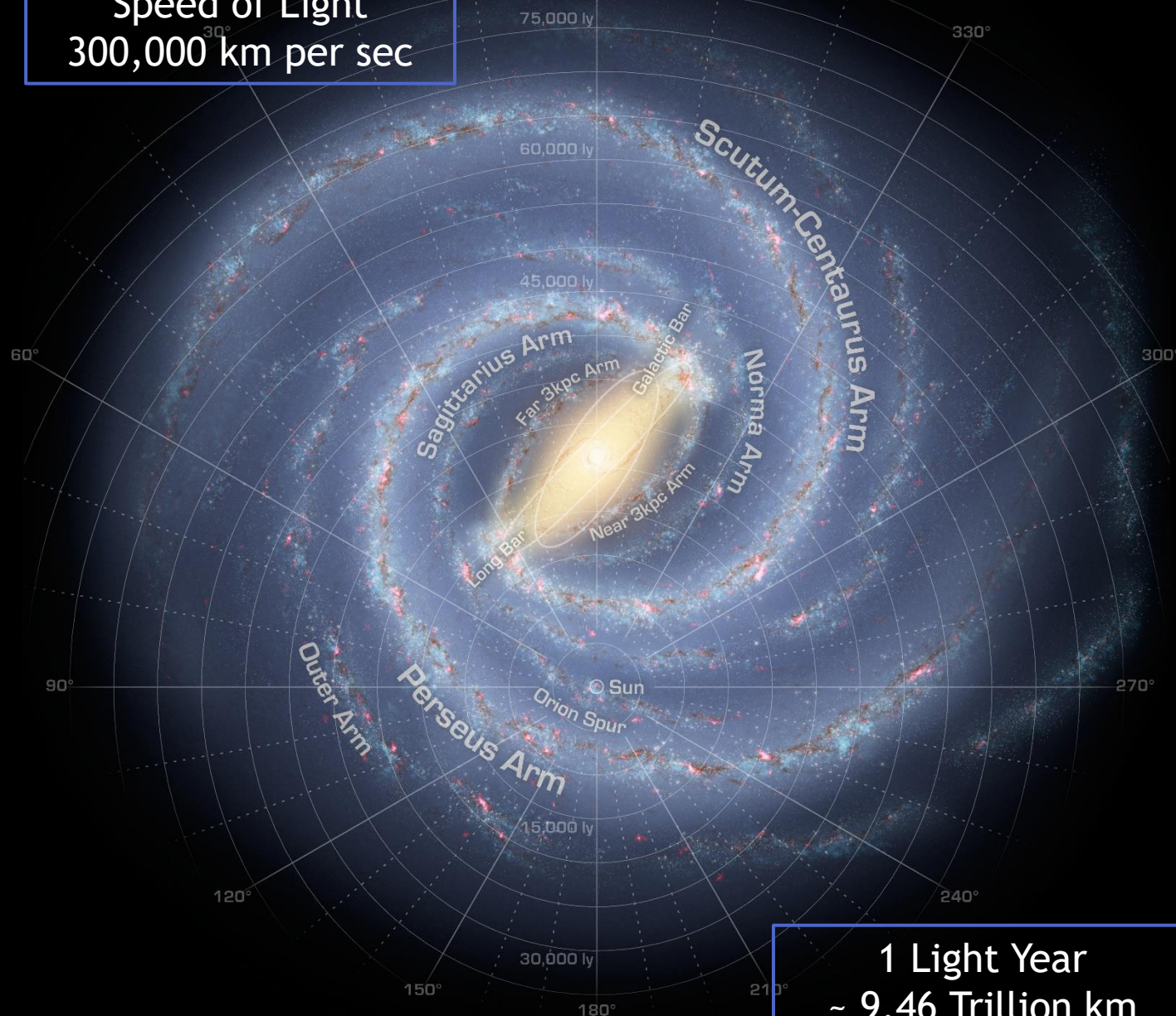


Orbital Speed of the Planets



Milky Way Galaxy

Speed of Light
300,000 km per sec



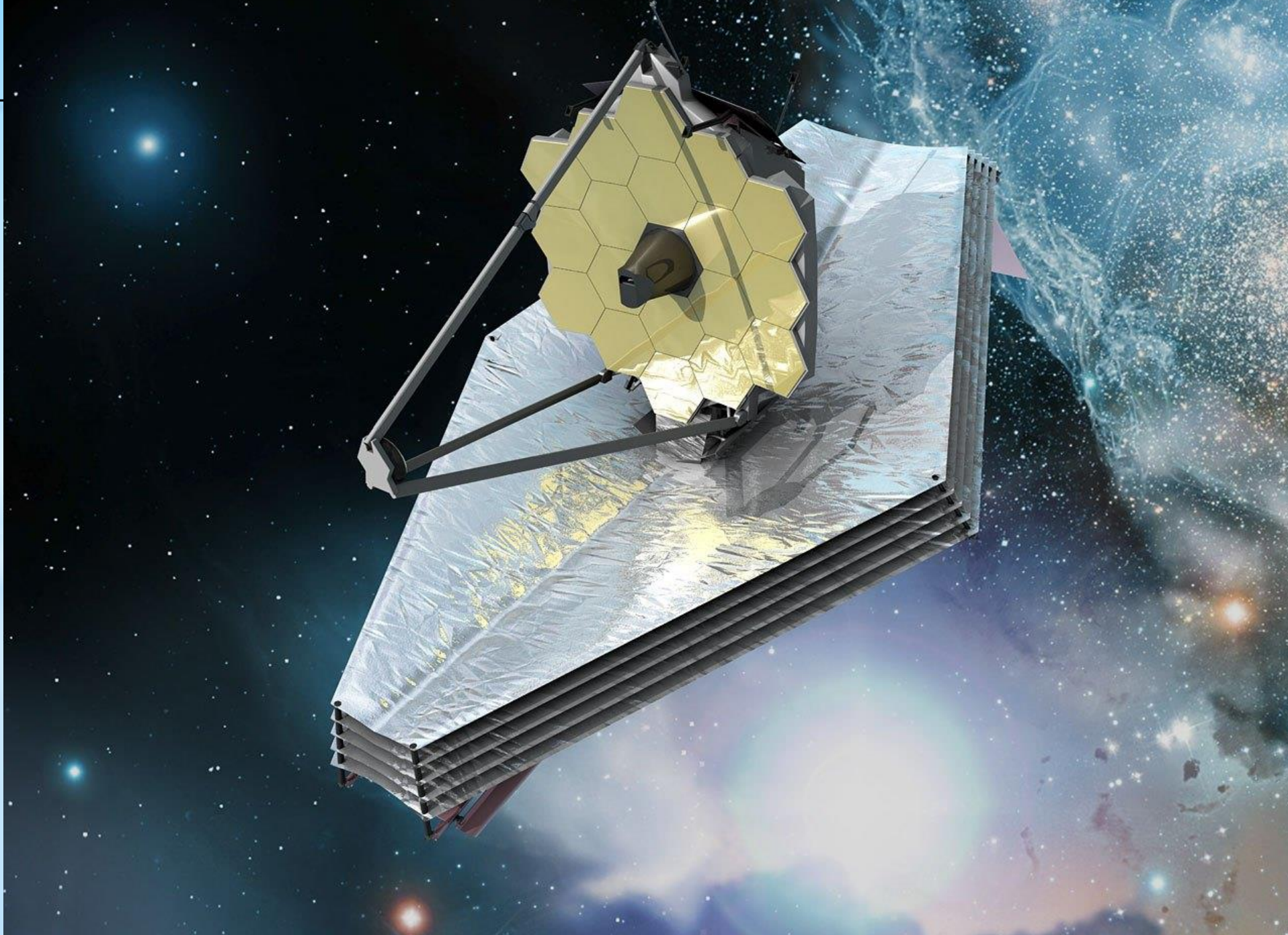
1 Light Year
~ 9.46 Trillion km

Hubble Telescope Repair Mission Crew (STS-125)





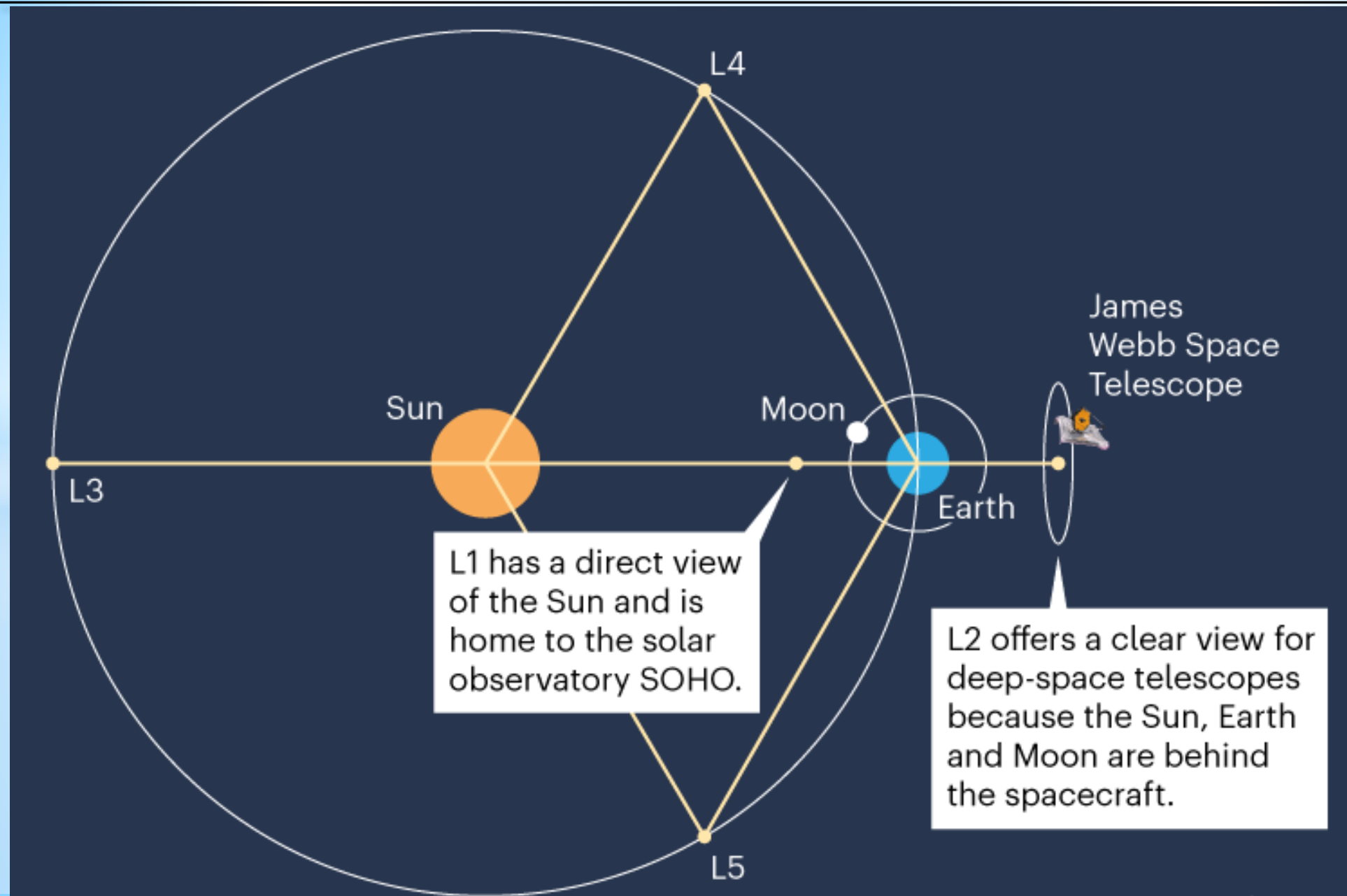
Webb Telescope

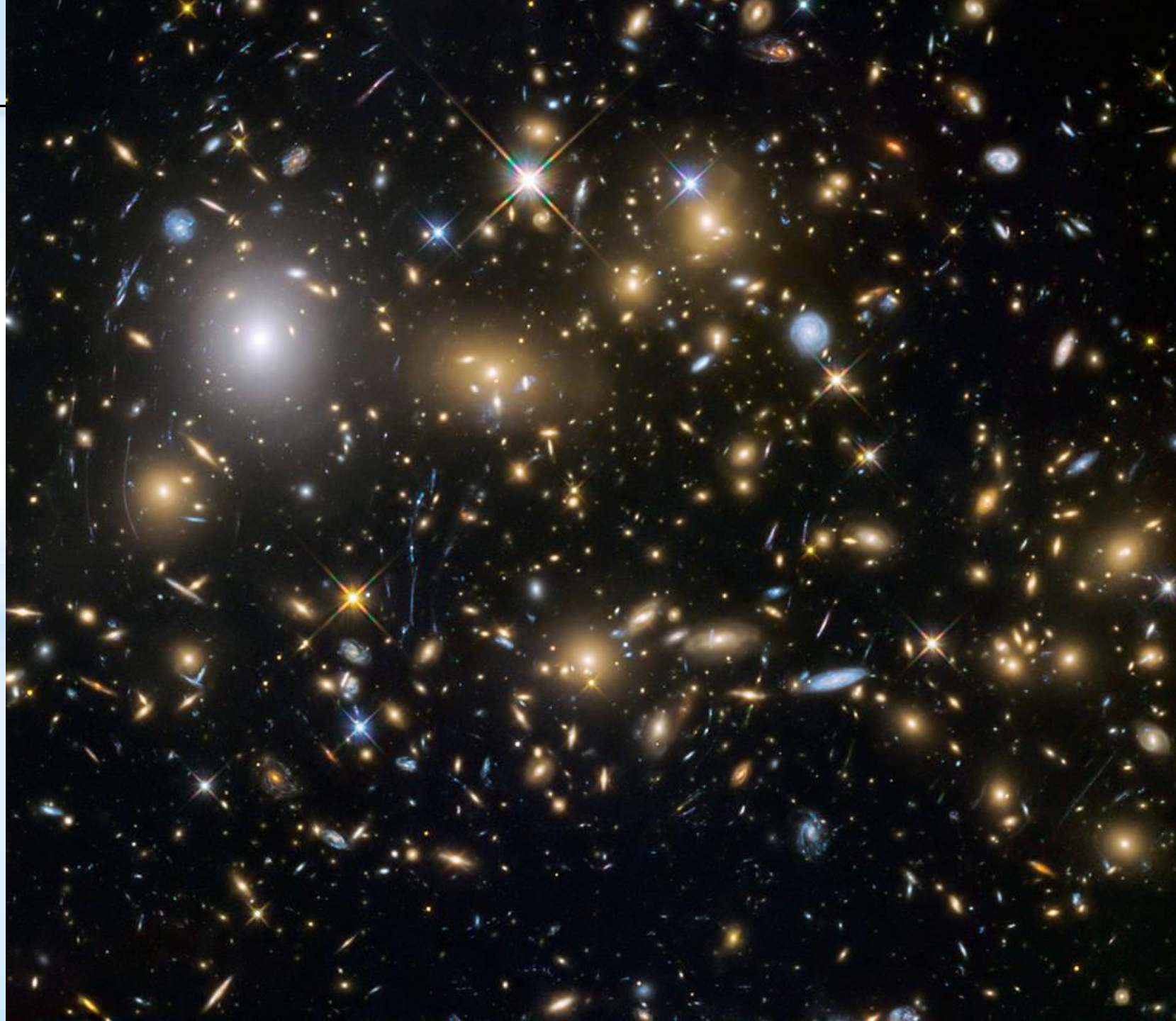


Webb Image during Mirror Alignment

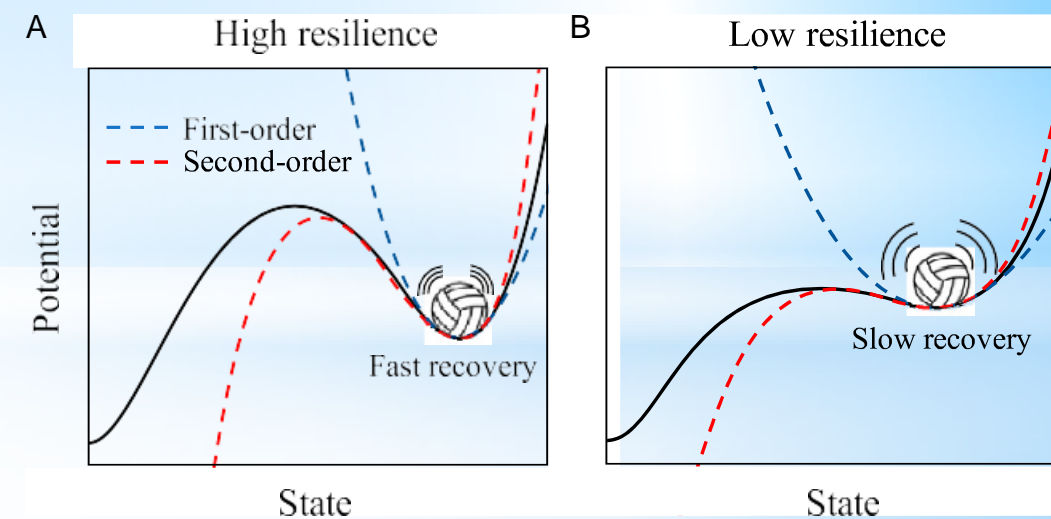
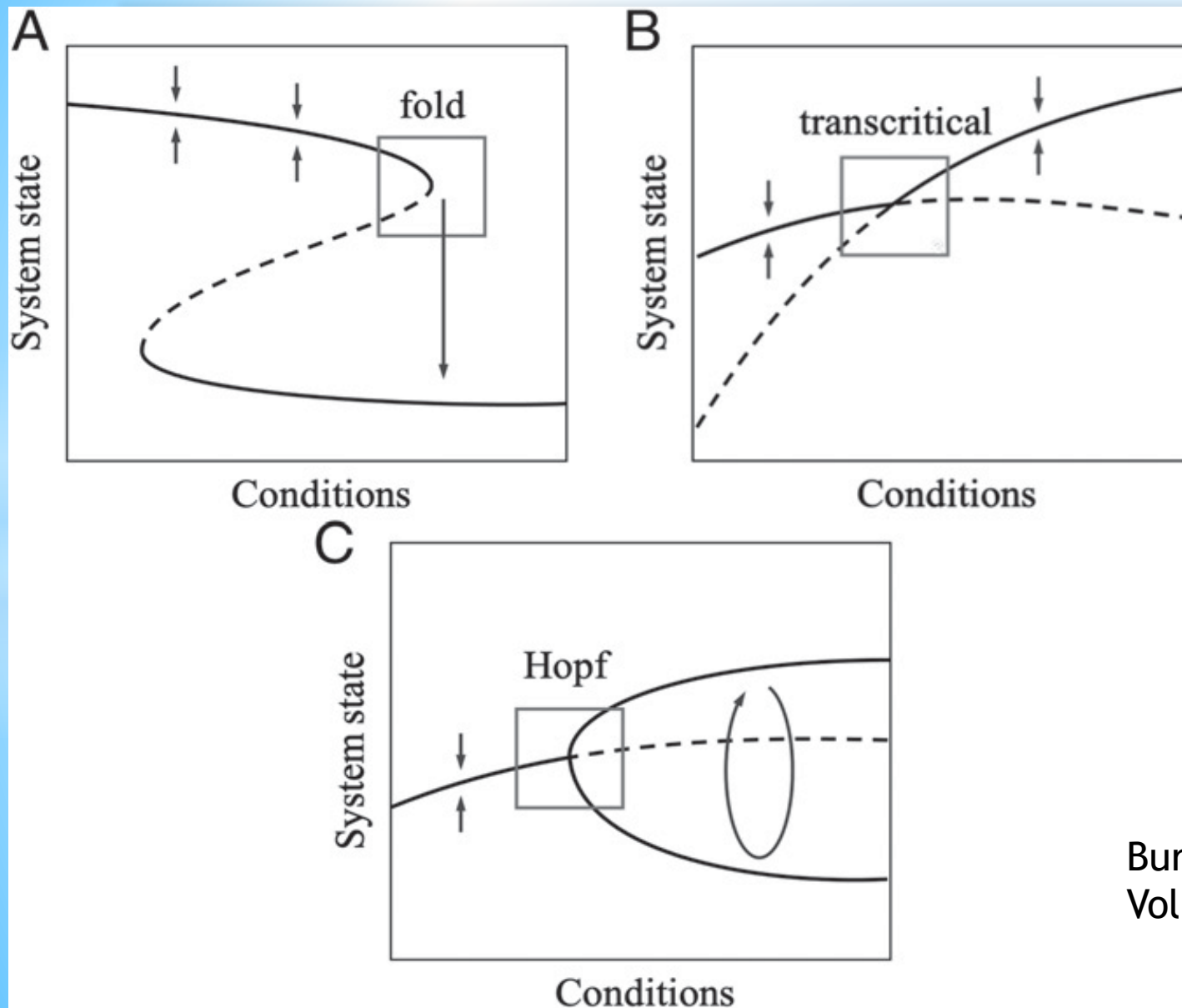


Webb and Lagrangian Point L2 (1.61 Million km)



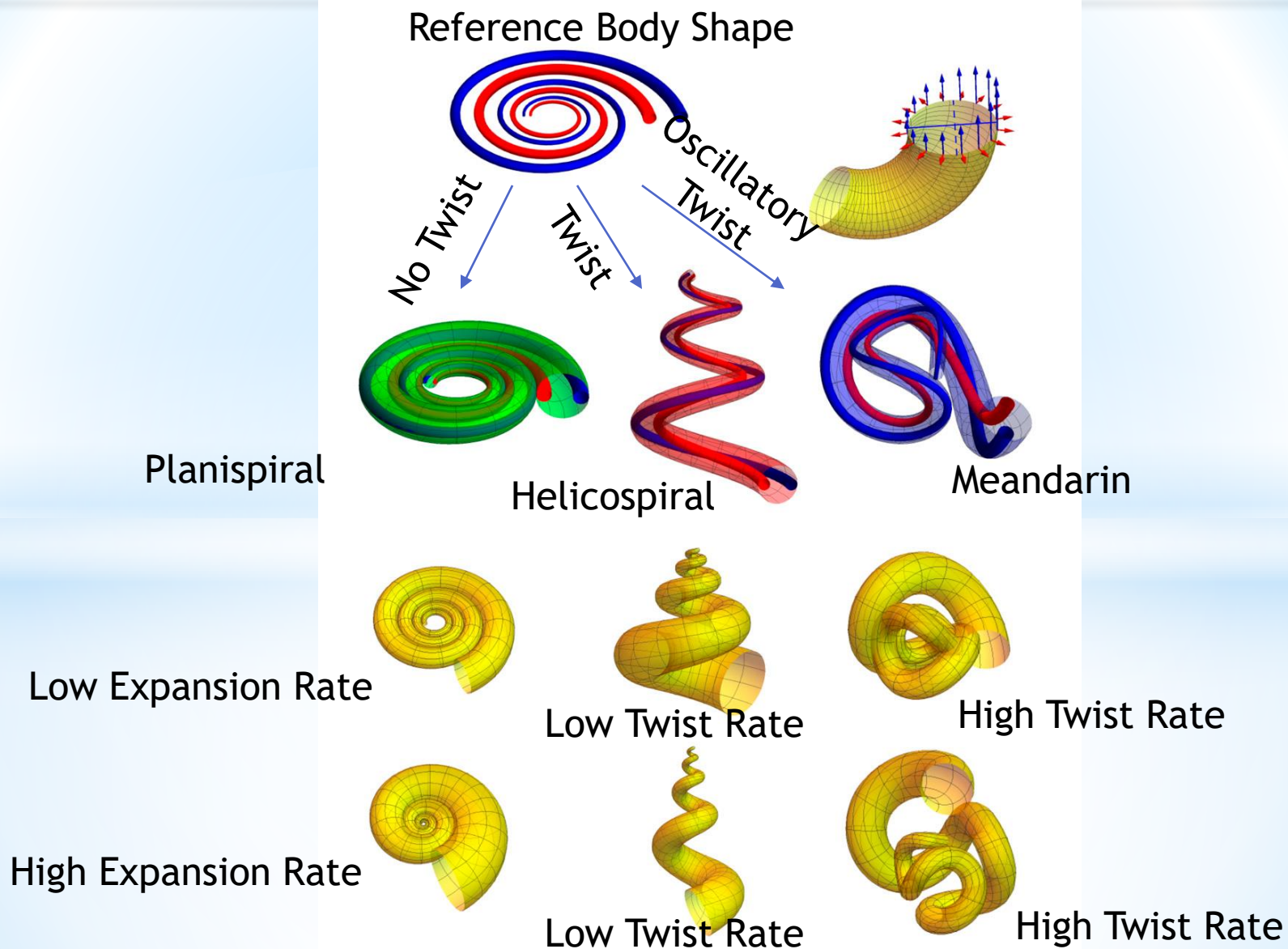


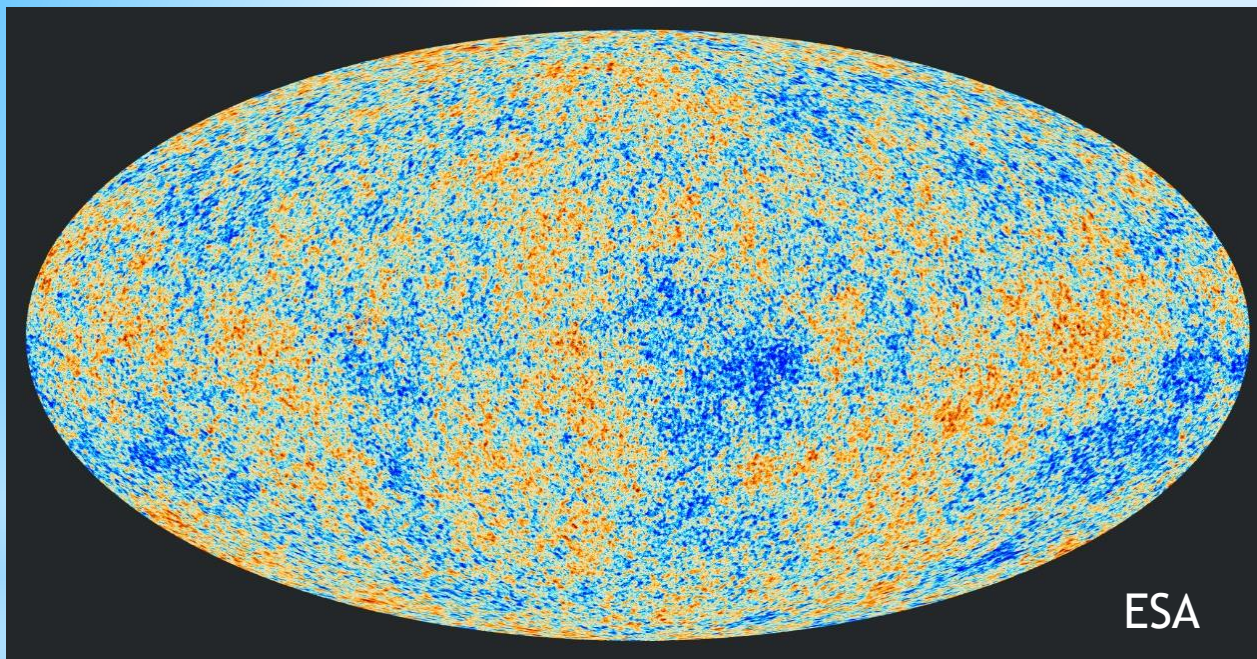
Tipping Points (Cozzarelli Prize) 2021)



Bury et. al., Proc. National Academy of Sciences,
Vol 118 (2021) No 39.

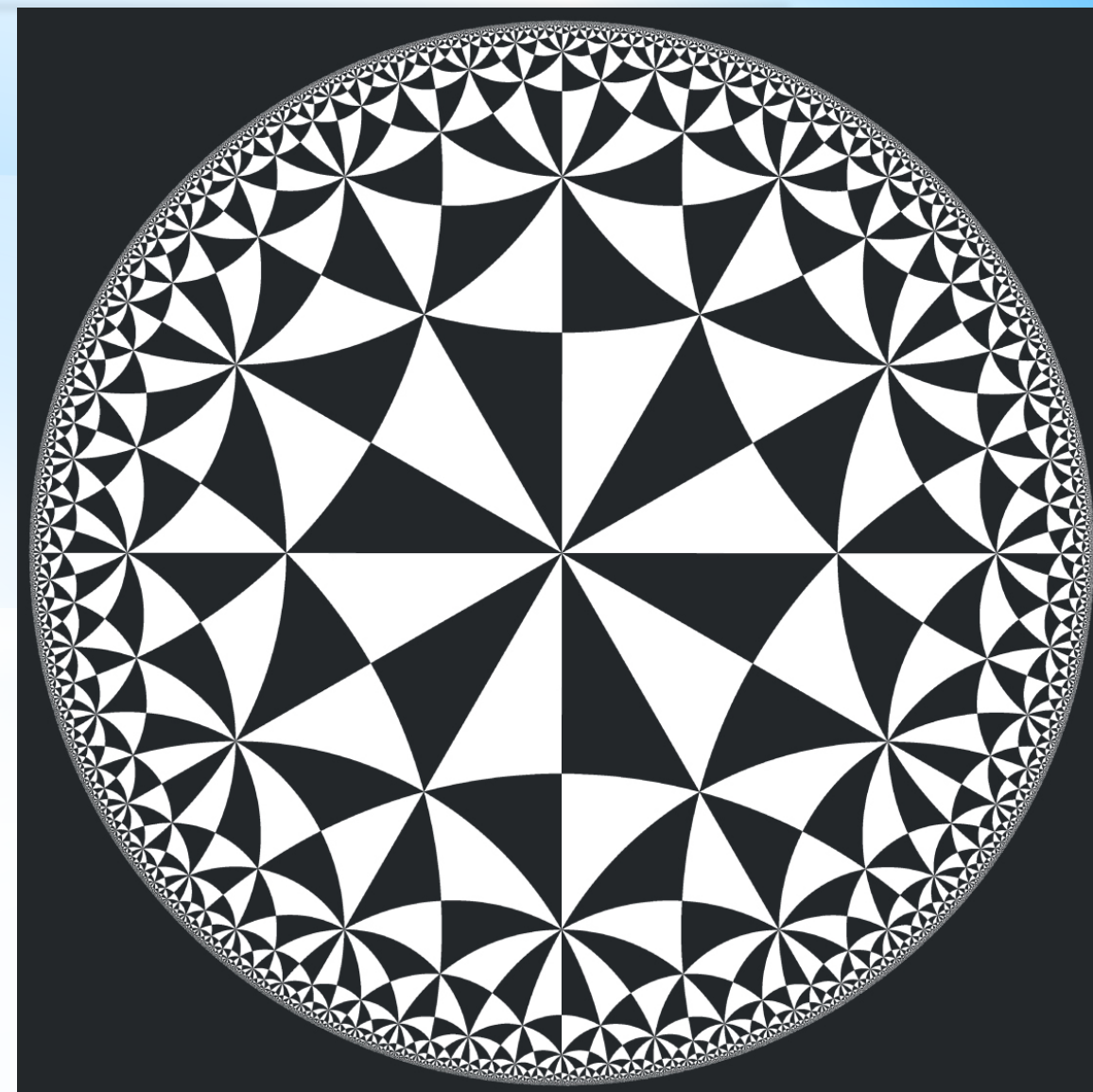
Shell Formation





Universe

Hyperbolic Geometry Expands Outward



Human can neither Create nor destroy a single atom

Human is capable of transforming existing material for the benefit of human race



Venus

Atmosphere : 94.5 % CO₂ and
4.5% N₂, SO₂

Temp : 470 deg Celsius

Pressure : 100 atm

Sun rises in West sets in East



Earth

Atmosphere : 80% N₂ and
20% O₂

Temp : -89 to 57 deg Celsius

Pressure : 1 atm

Sun rises in East sets in West



Mars

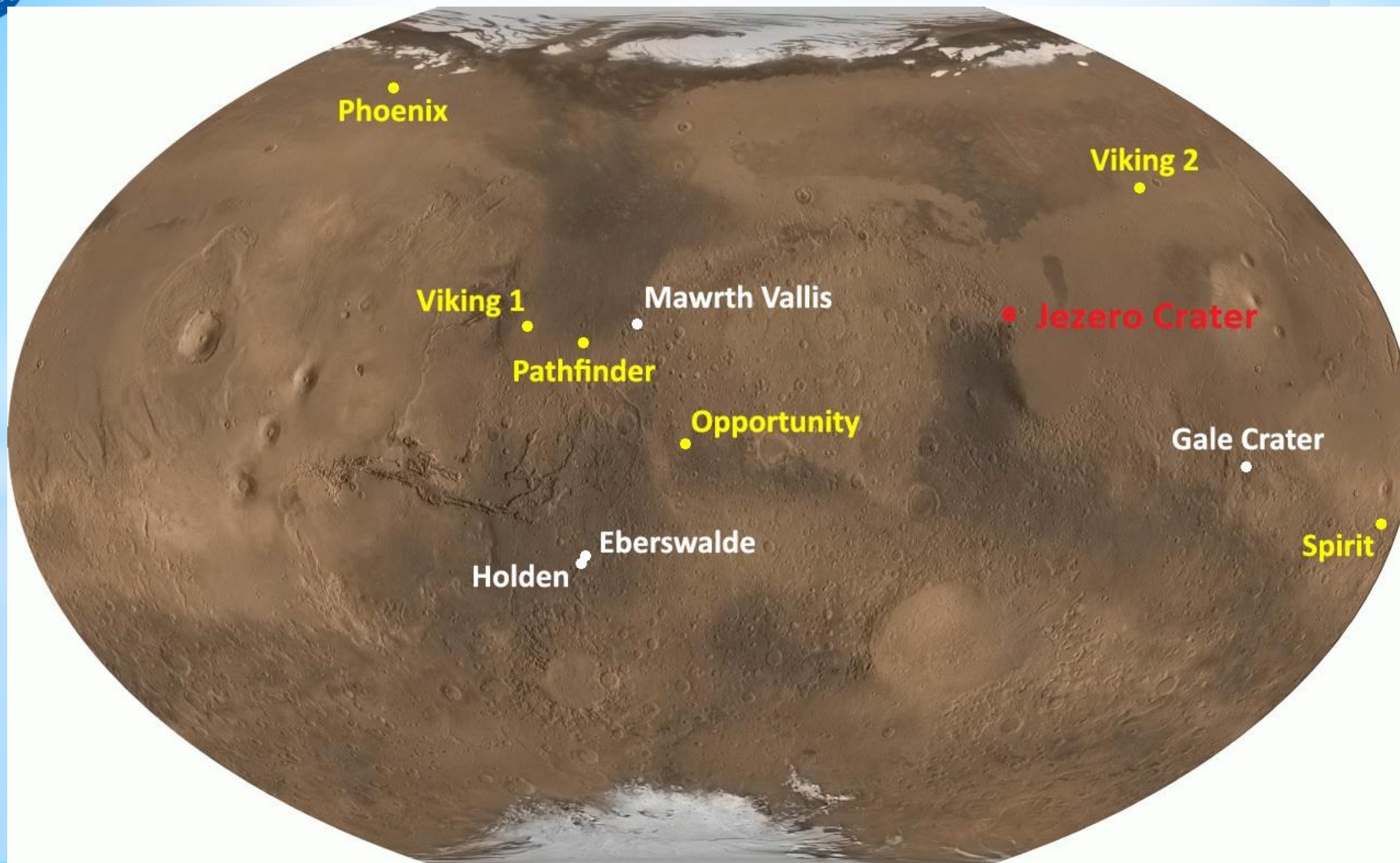
Atmosphere : 95% CO₂ and 5%
N₂ and Ar

Temp : -140 to 20 deg Celsius

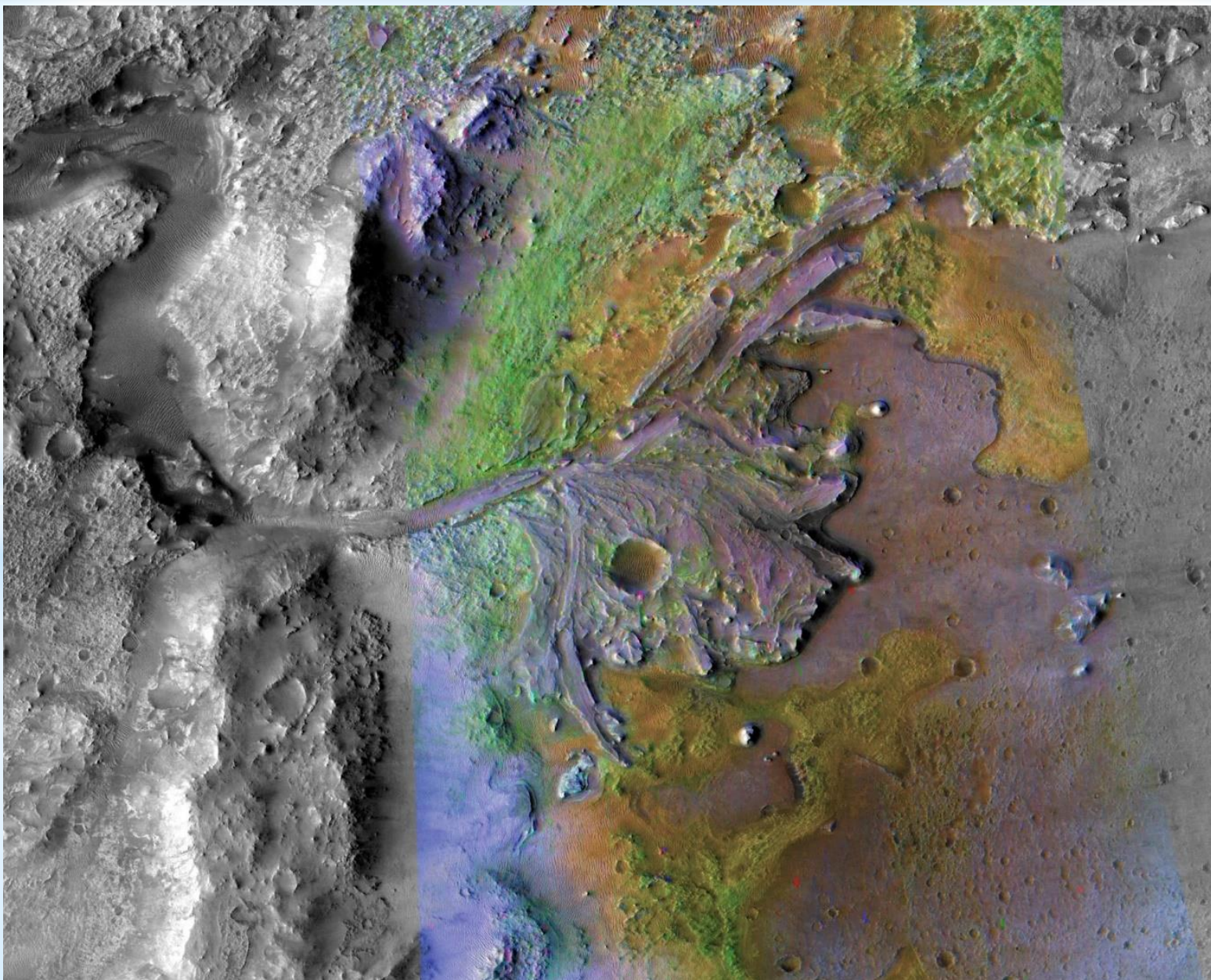
Pressure : 0.006 atm

Sun rises in East sets in West 19

Mars Landing Sites



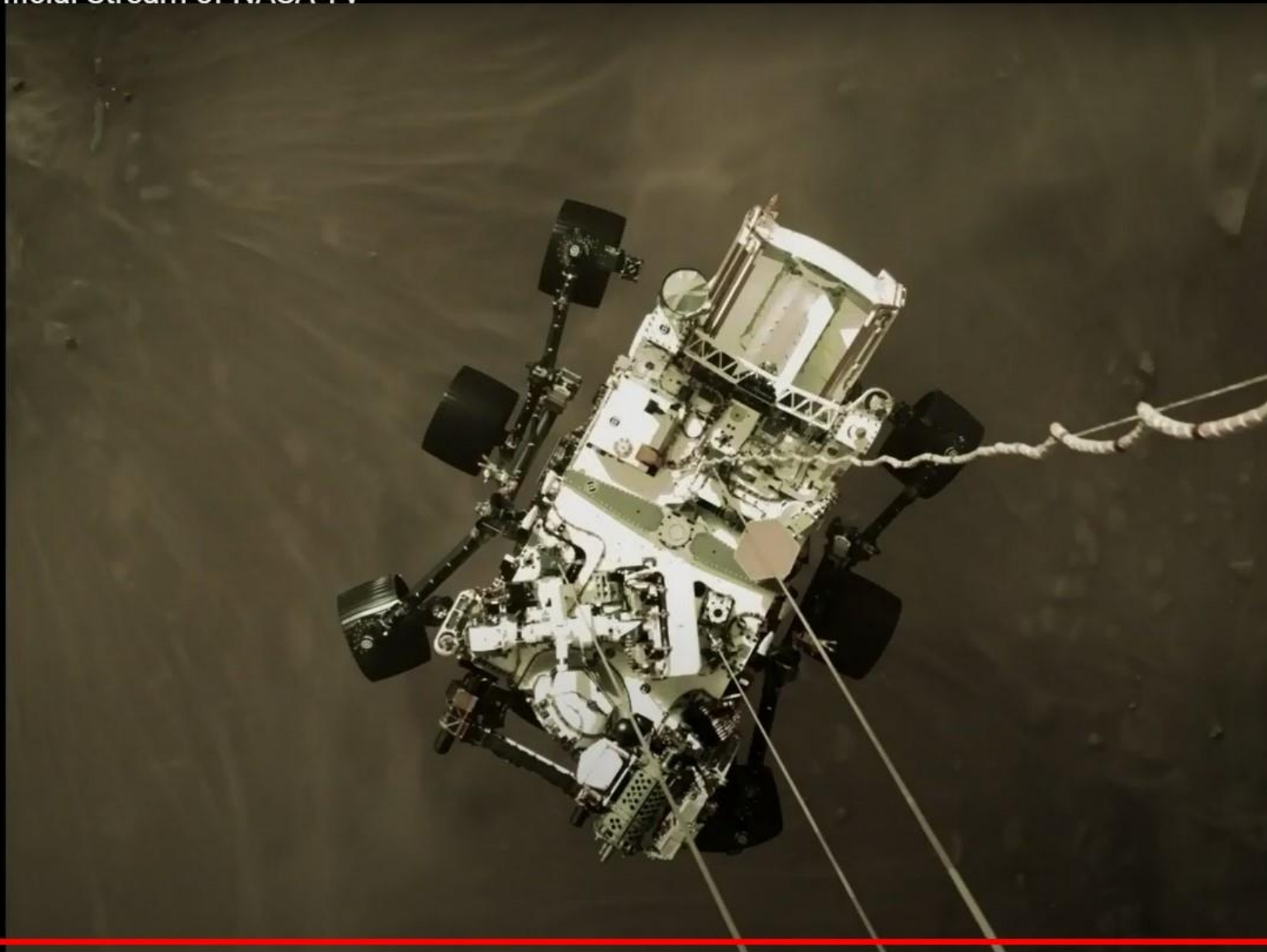
Mars 2020 : Jezero Crater





Perseverance Landing

NASA Live: Official Stream of NASA TV

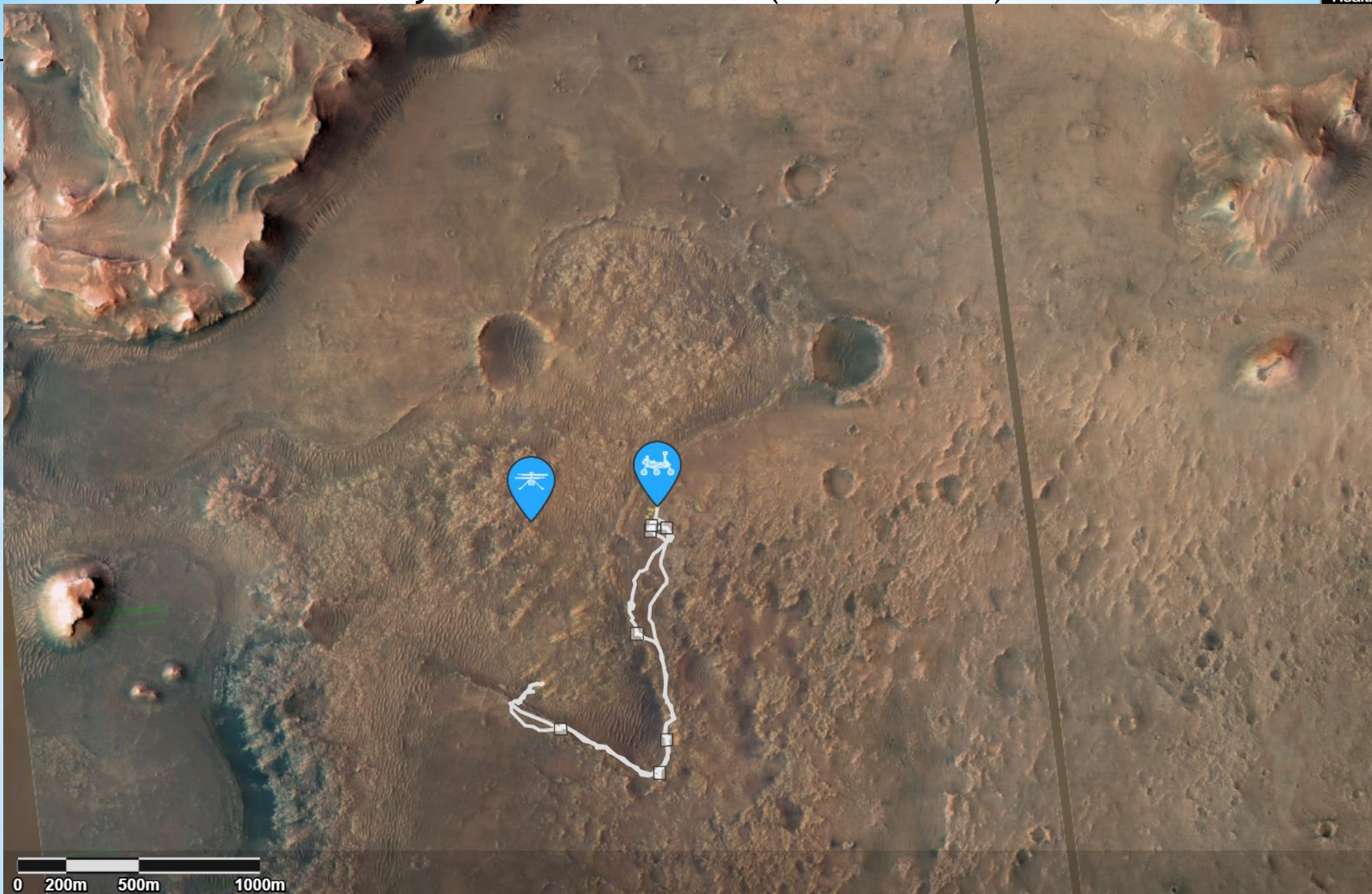


Scroll for details
v



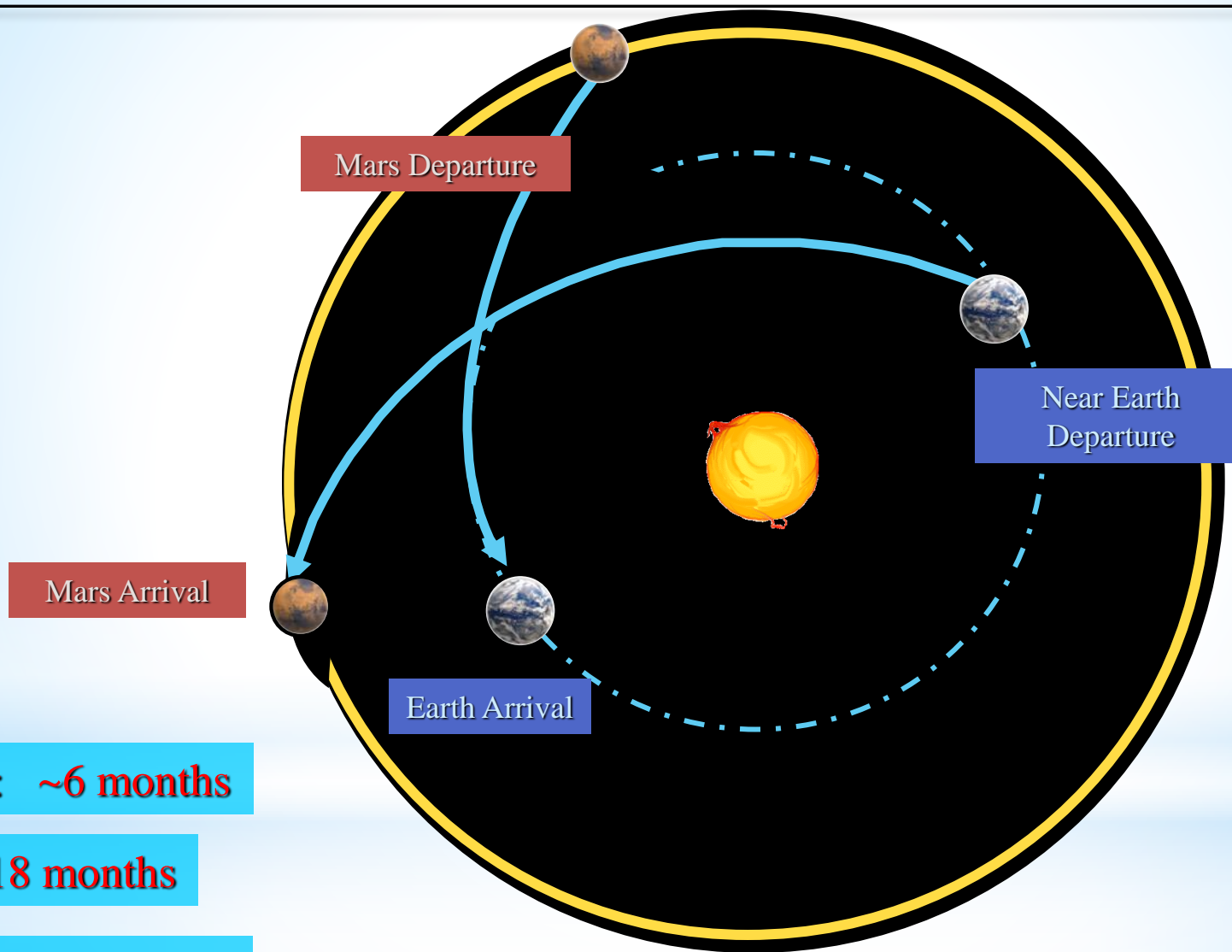


Percy at Jezero Crater (March 2022)





Overview of Notional Mars Expedition



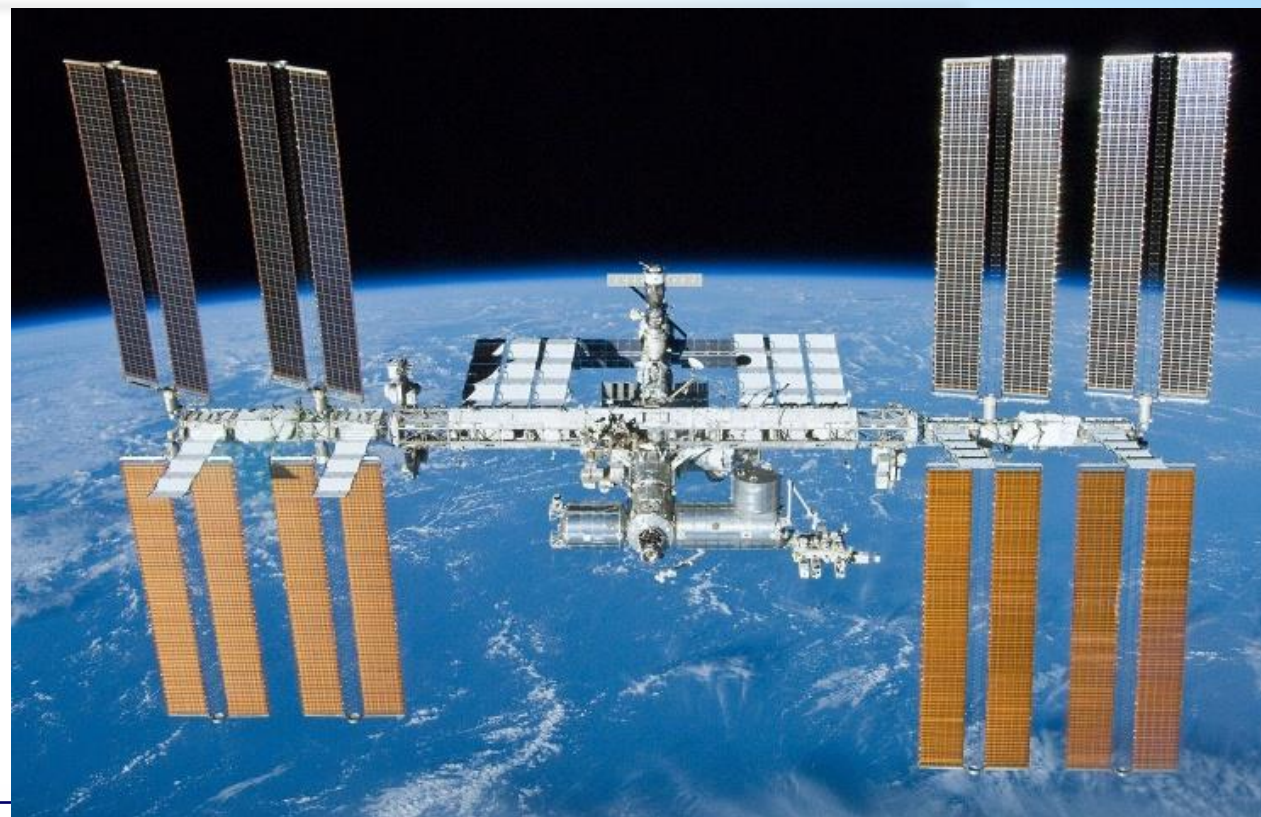
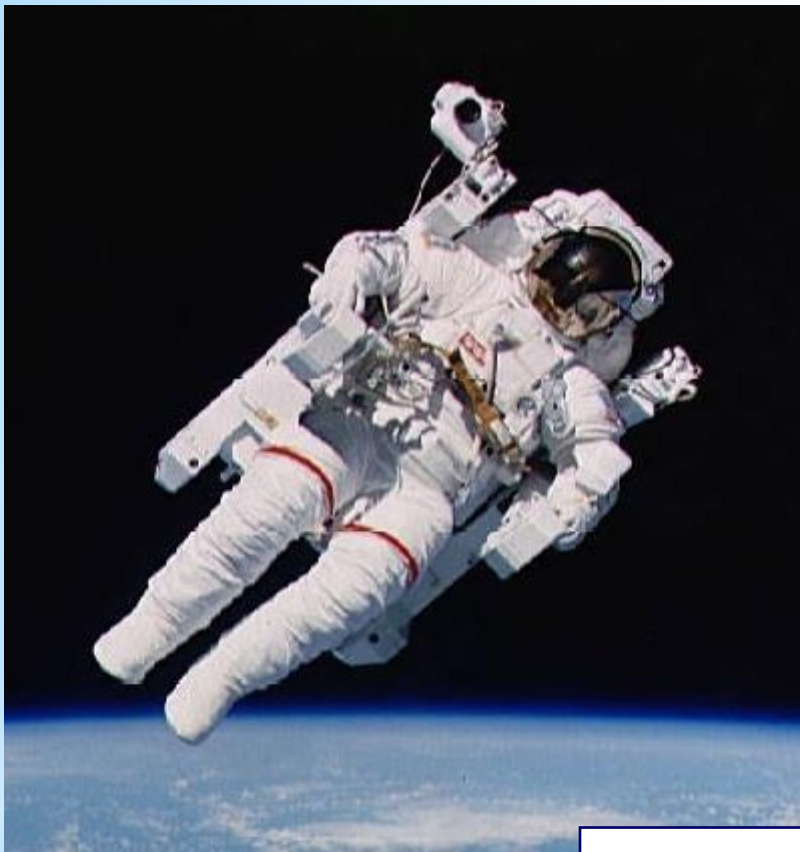
Earth-to-Mars transit: ~6 months

Mars surface stay: ~18 months

Mars-to-Earth transit: ~6 months



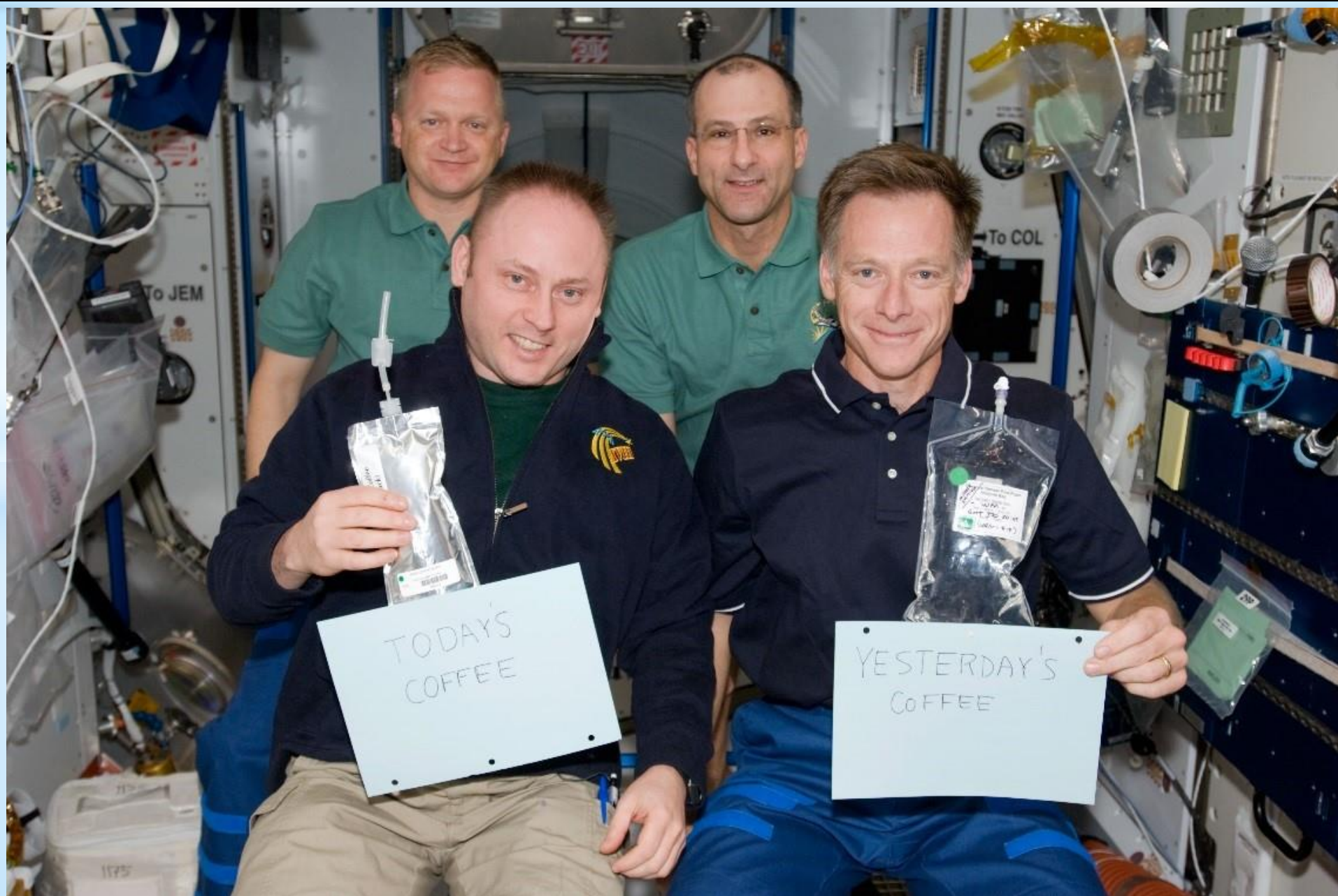
Living in a Closed System

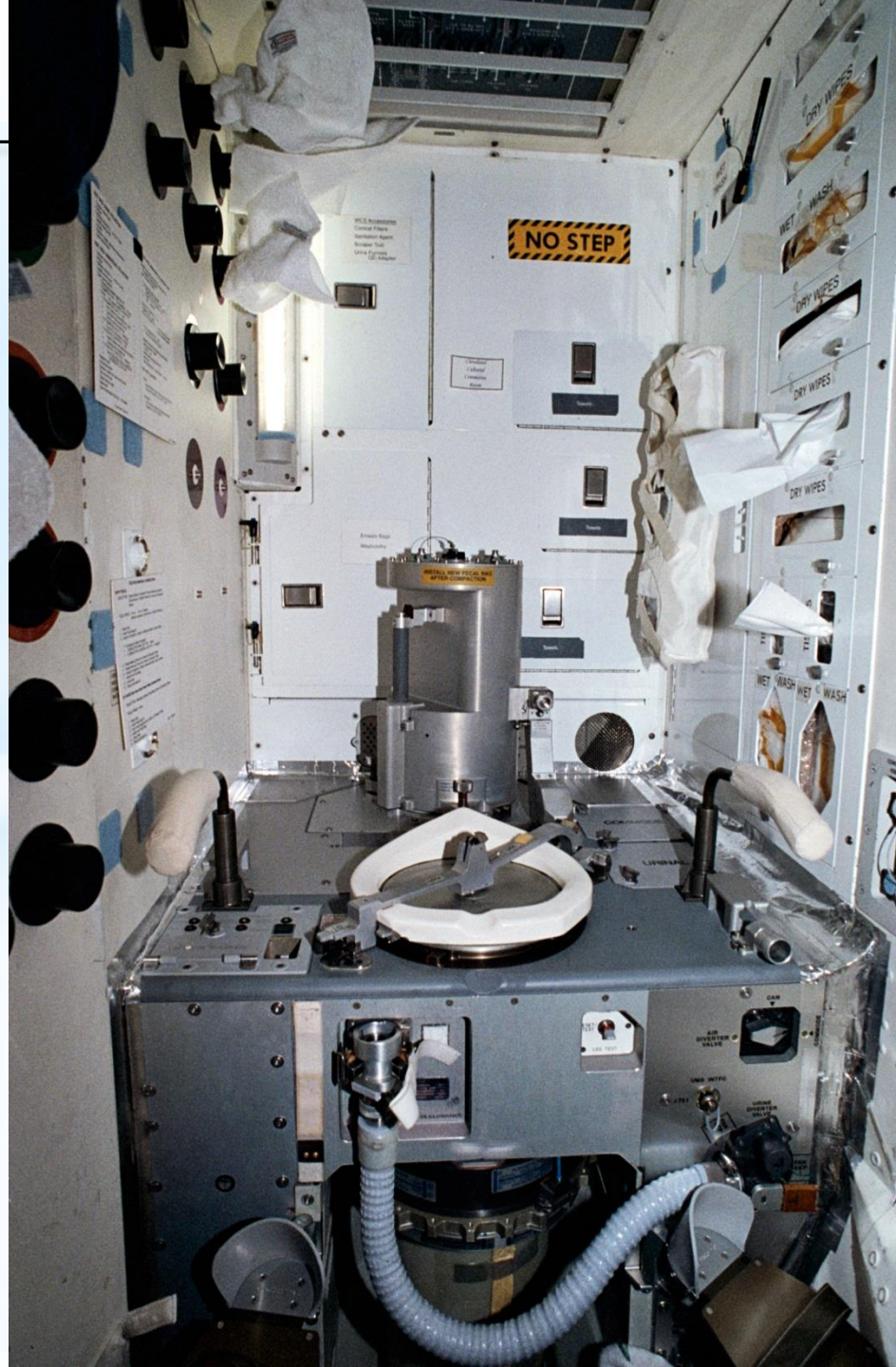


Recycling

- Water Regeneration Reactors
 - Air Revitalization Reactors
 - Environmental Sensors
 - Microbial Monitors

Today's Coffee - Yesterday's Coffee



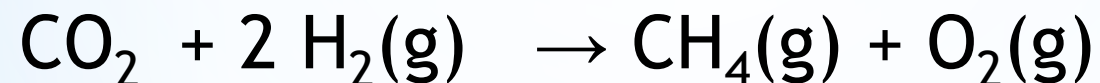


- Lithium Hydroxide
- Zeolite
- Amine Bed
- Anchored Amine Bed
- Sabatier Reaction

- Oxygen Generation System (Electrolysis)



- Sabatier Reaction



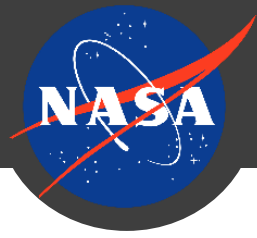
Air Quality Monitoring



D. Gazda
T. Limero

AQM 1 (624 column)	AQM 2 (DB5 column)
Acetone	Ethanol
Hexane	Dichloromethane
1,2-dichloroethane	Trimethylsilanol
Toluene	2-butanone
Hexamethylcyclotrisiloxane	Ethyl acetate
Hexanal	N-butanol
m,p-xylene	Toluene
o-xylene	Hexamethylcyclotrisiloxane
Octamethylcyclotetrasiloxane	m,p-xylene
Decamethylcyclopentasiloxane	o-xylene
Acrolein	Octamethylcyclotetrasiloxane
Isopropanol	Decamethylcyclopentasiloxane
Benzene	

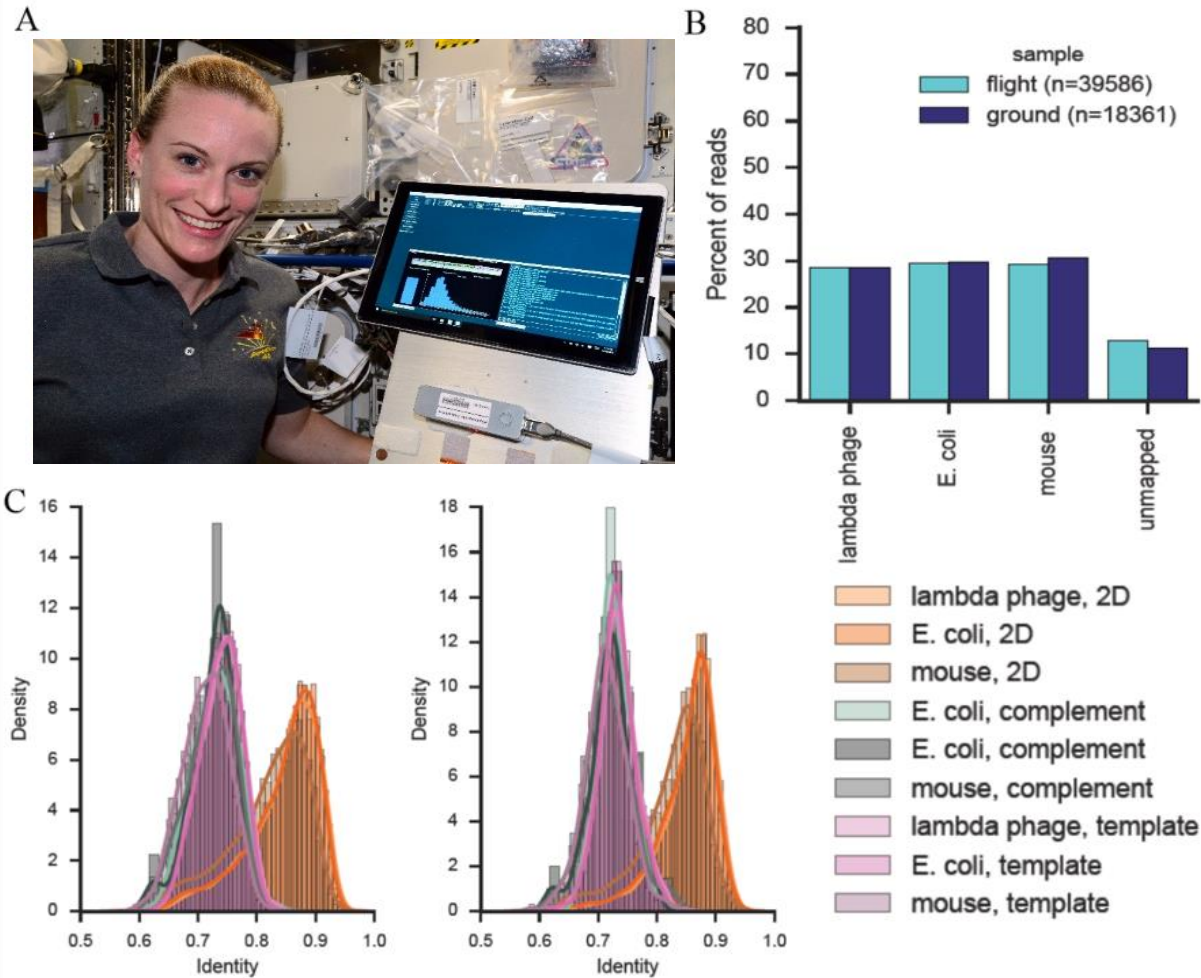
DNA Sequencing in Space!



MinION (Oxford Nanopore Technologies)

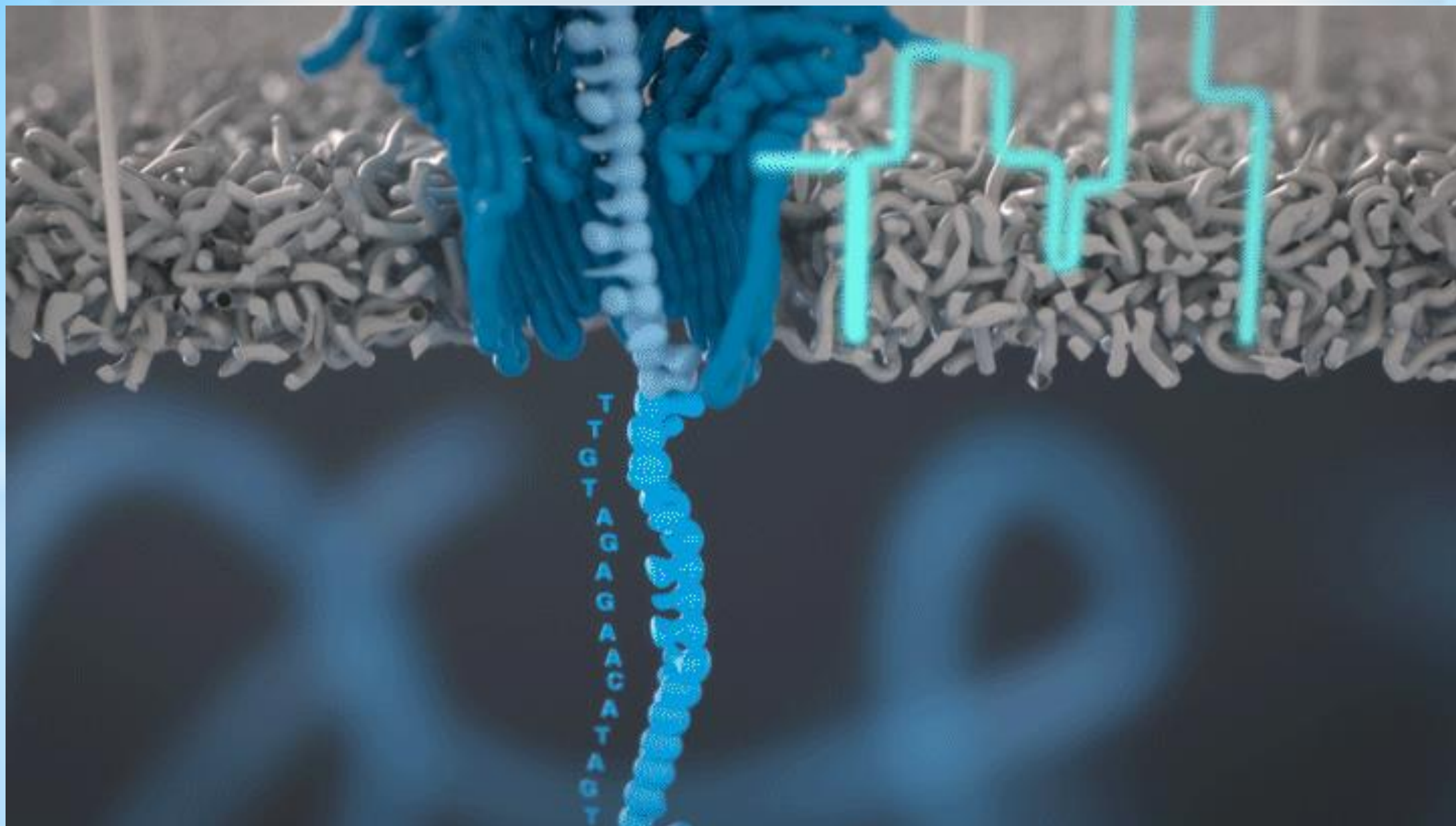


Biomolecule Sequencer Payload



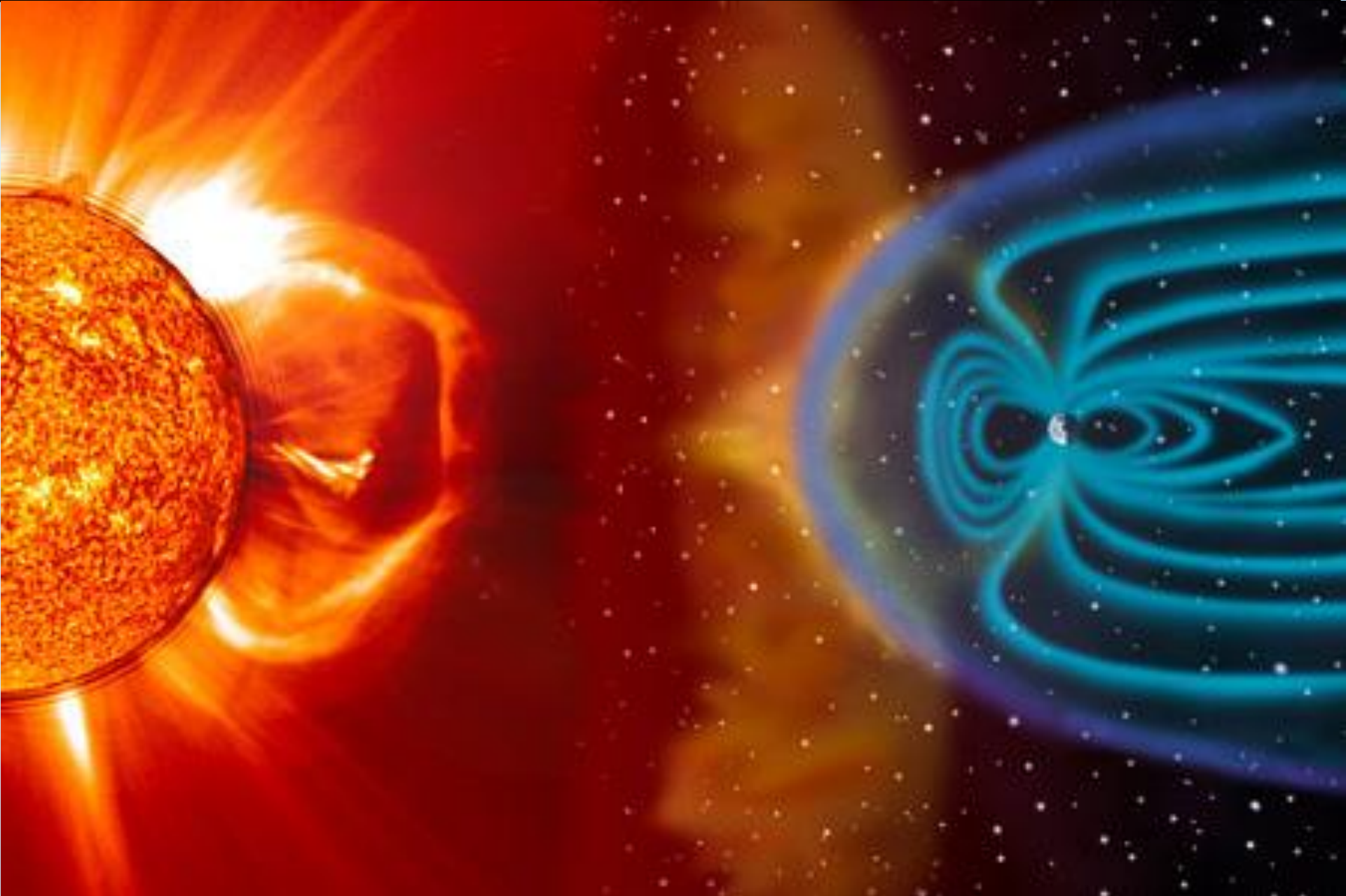
Castro-Wallace et al. <https://www.nature.com/articles/s41598-017-18364-0>

Nanopore Technology





Solar Flare and Earth's Magnetic Field



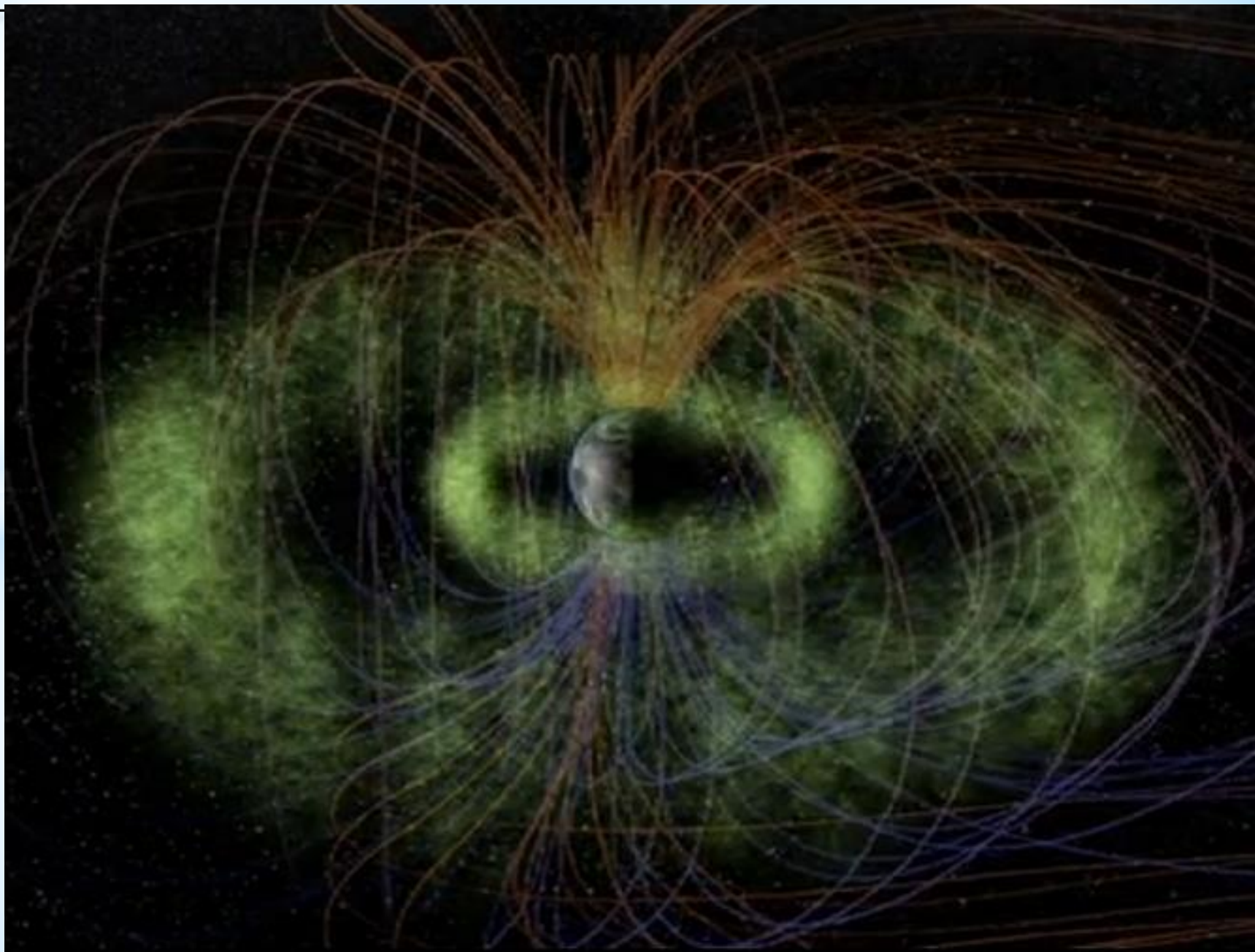
Auroras from ISS



Van Allen Belt

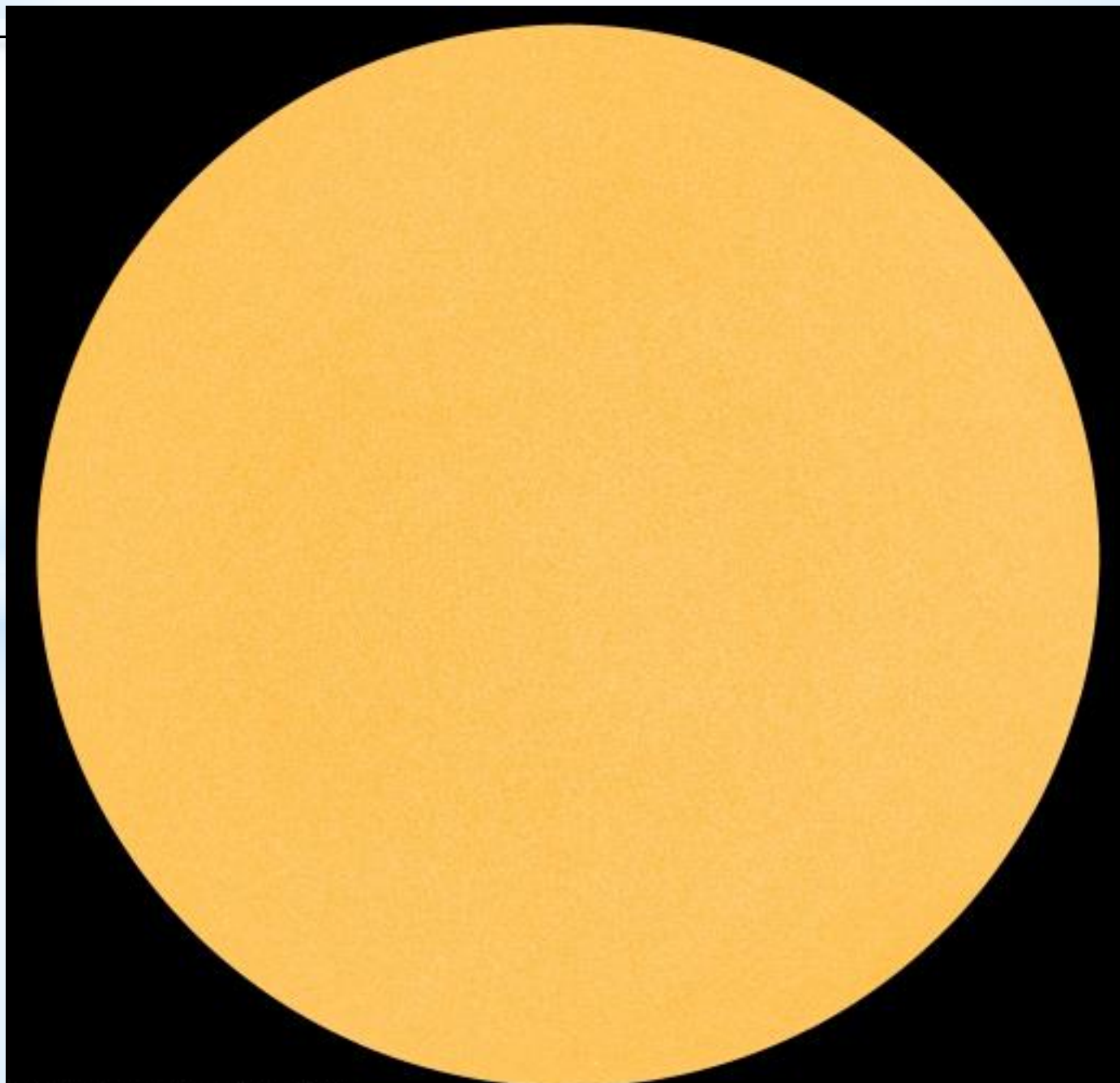
Inner Belt
Protons
640-960 km

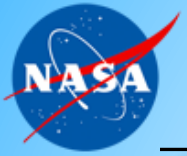
Outer Belt
Electrons 13,400-
57,000 km



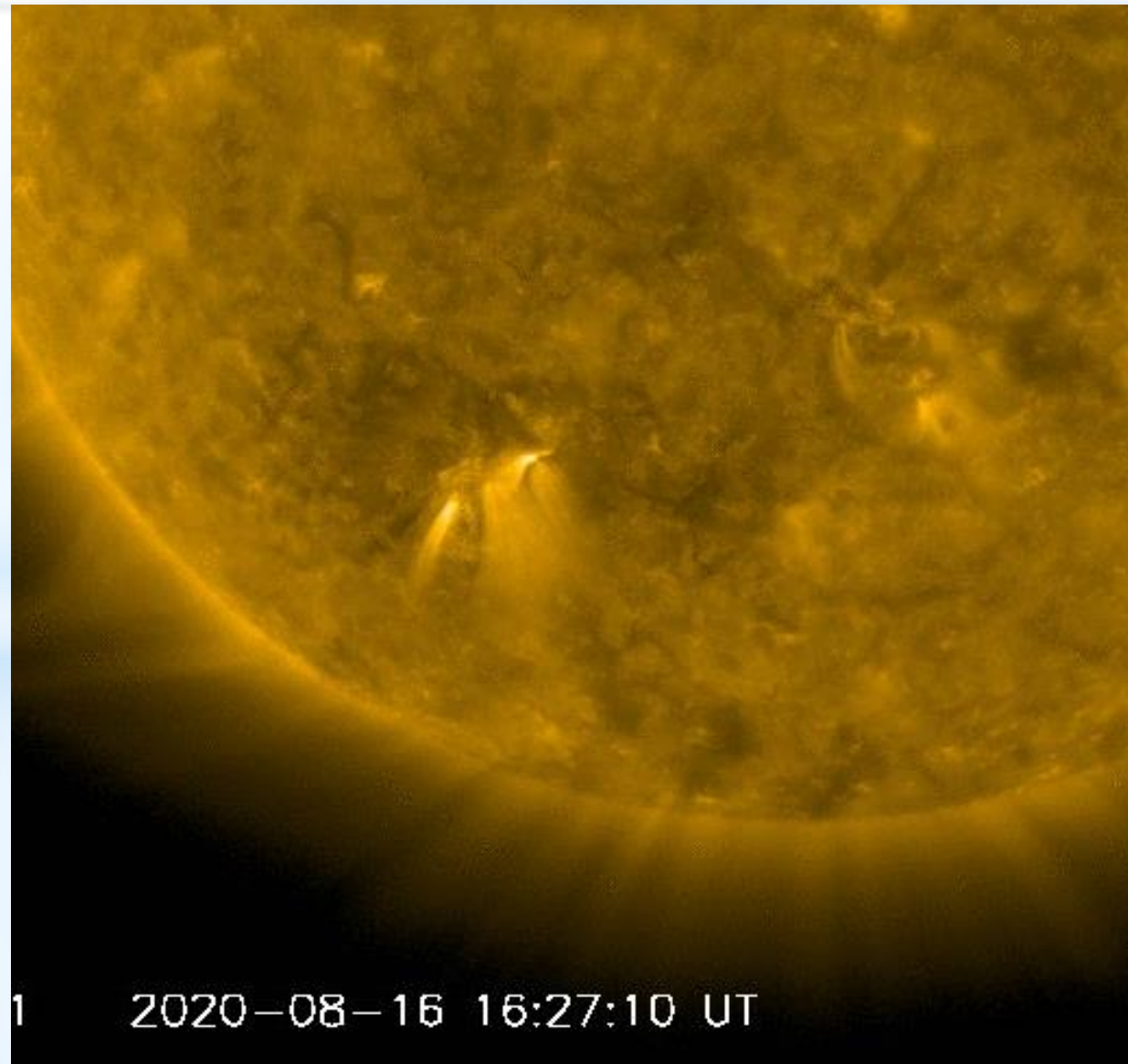


Spotless Sun 2019



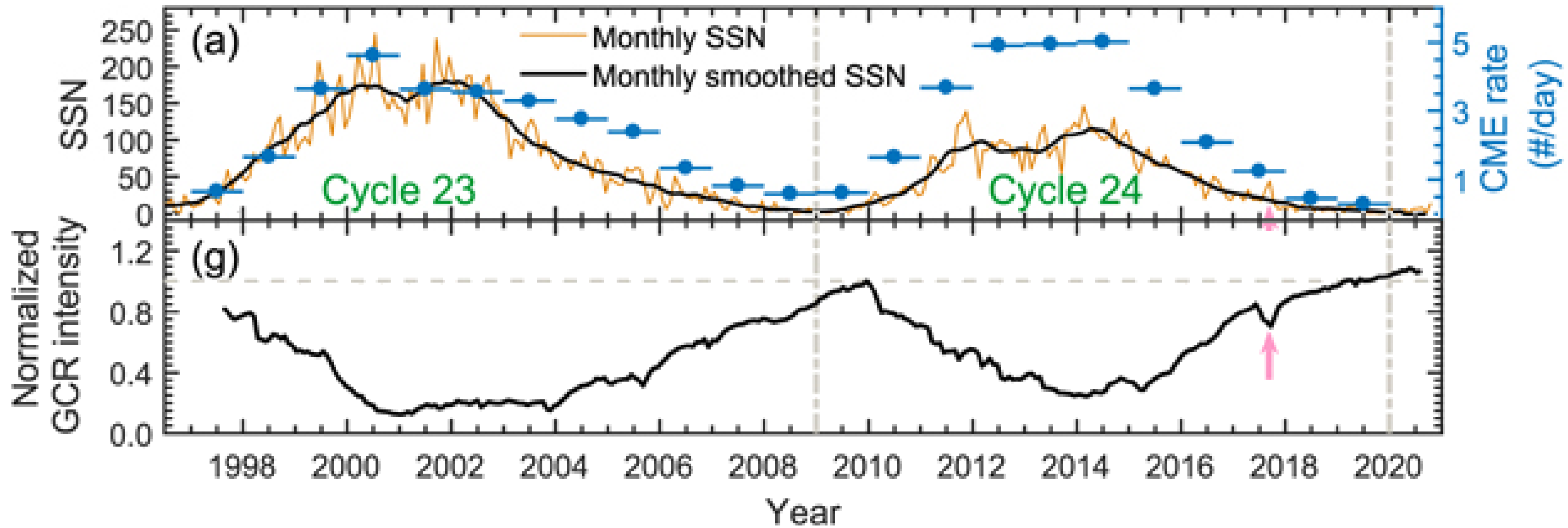


Solar Flare Aug 16, 2020



Solar Flare and Earth (Size Comparison)





Fu et. Al., The Astrophys. Journal, Vol 254 (2021) 37.

Scott Kelly (1 Year Mission) Twin Studies





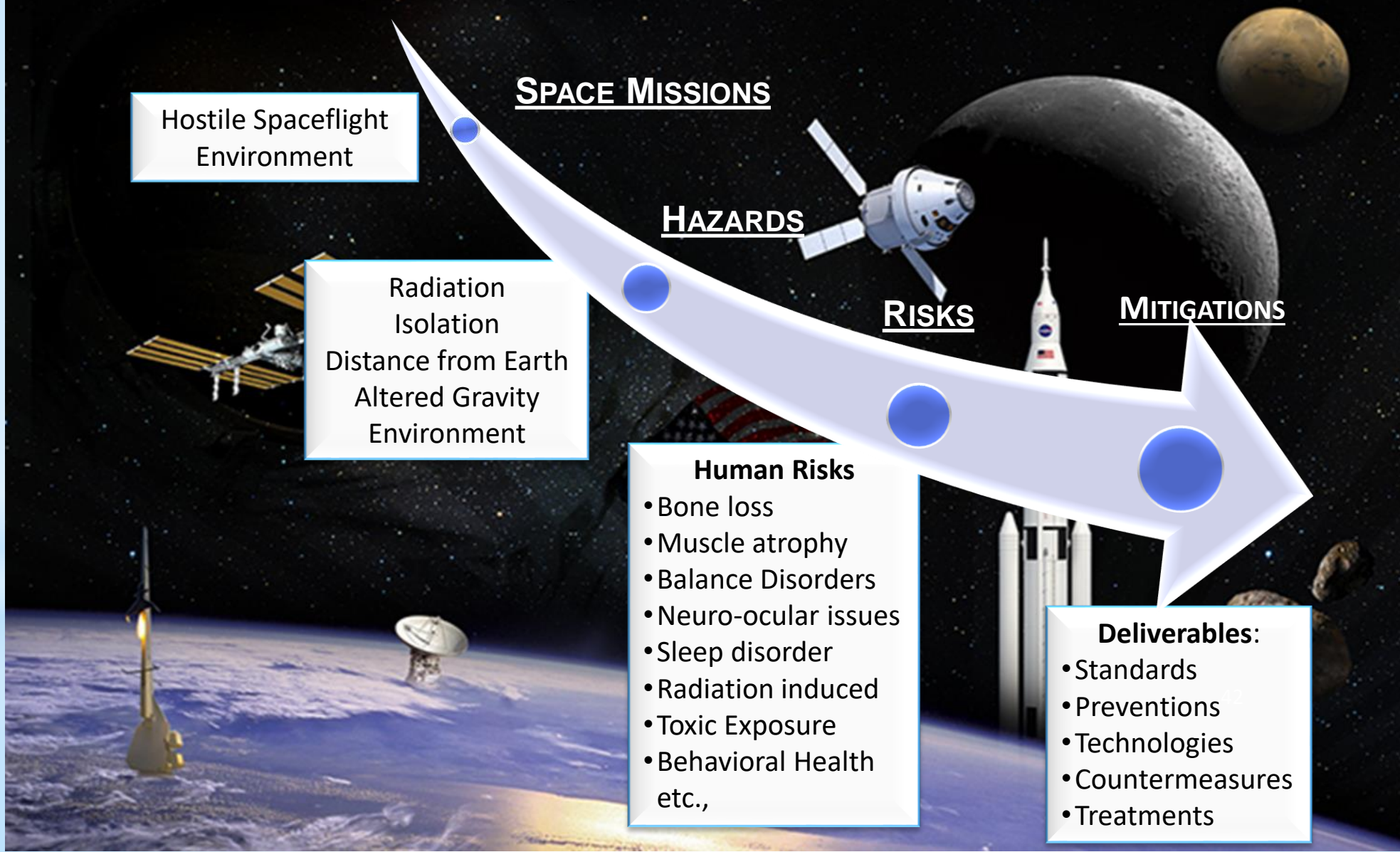
Sleep





Human Health & Performance

Enable successful space exploration by minimizing the Human System Risks of spaceflight hazards





Hazards of Spaceflight (RIDGE)

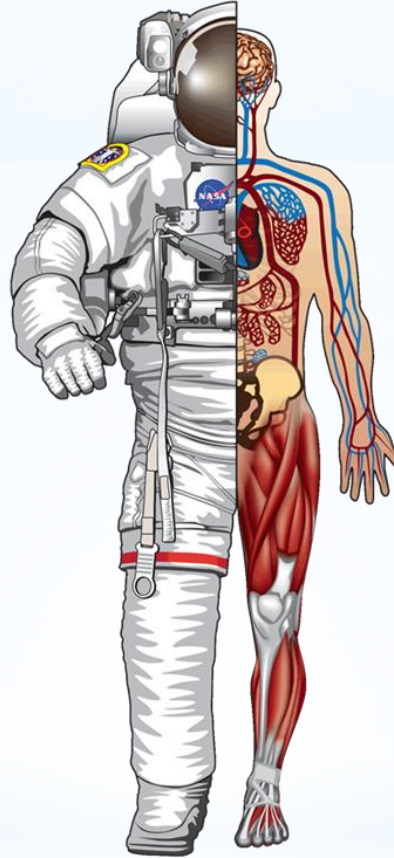
Hazards Drive Human Spaceflight Risks

Radiation

Acute In-flight effects
Long term cancer risk

Distance from earth

Autonomous Medical Care
and Operations;
Communication Delay



Isolation & Confinement

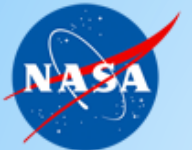
Behavioral aspect of
isolation
Sleep disorders

Altered Gravity - Physiological Changes

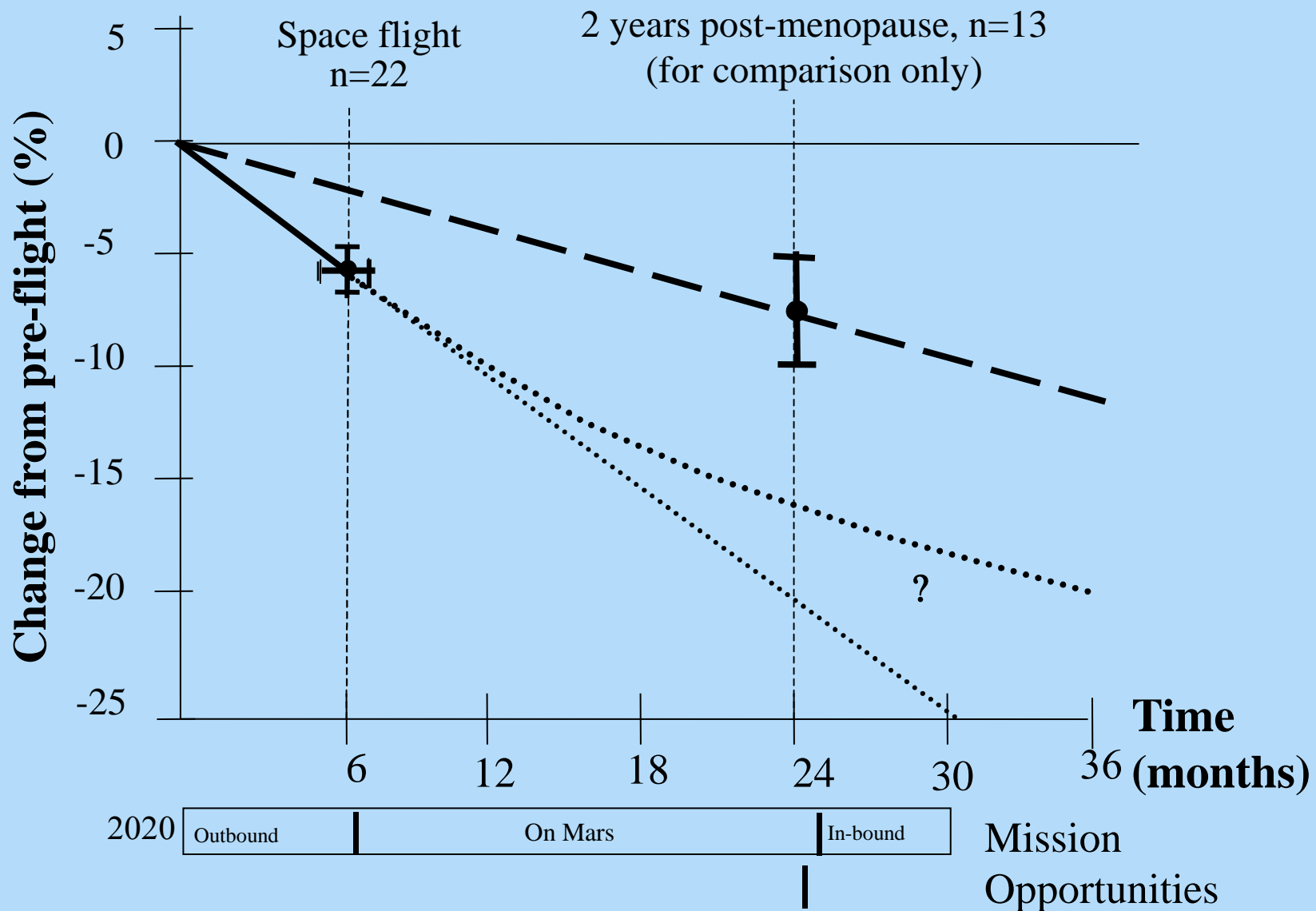
Balance Disorders
Fluid Shifts
Cardiovascular Deconditioning
Decreased Immune Function
Muscle Atrophy
Bone Loss

Environment (Closed/Hostile)

Vehicle Design
Environmental – CO₂ Levels,
Toxic Exposures, Water,
Food



Bone Loss During Space Missions





Treadmill in International Space Station

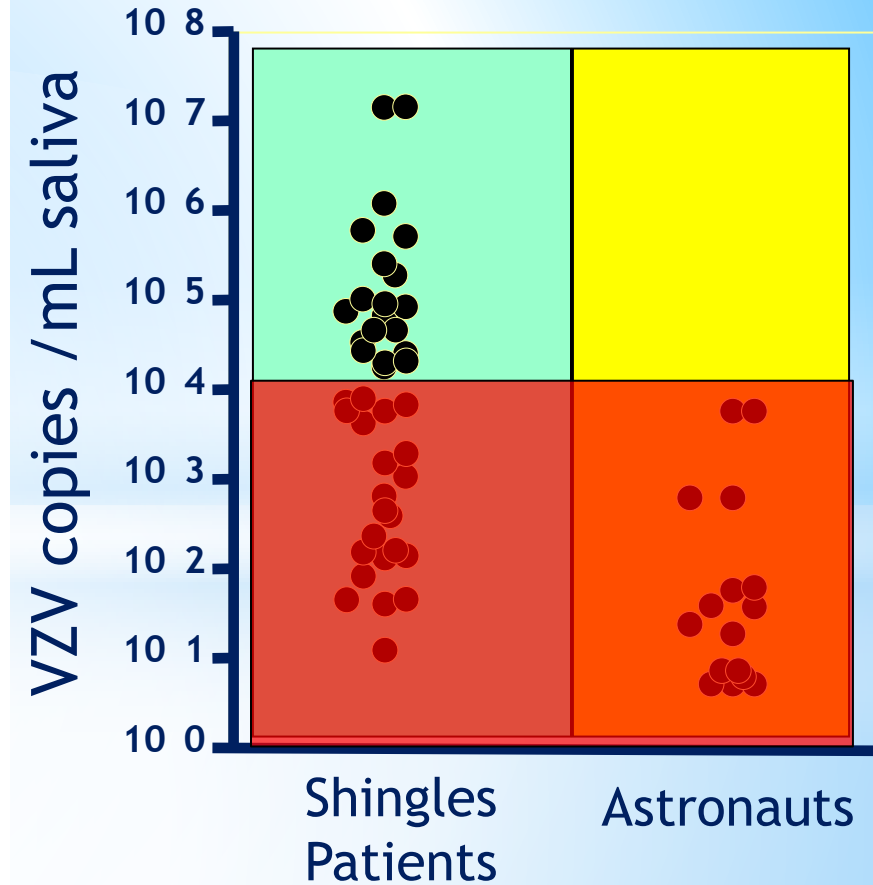
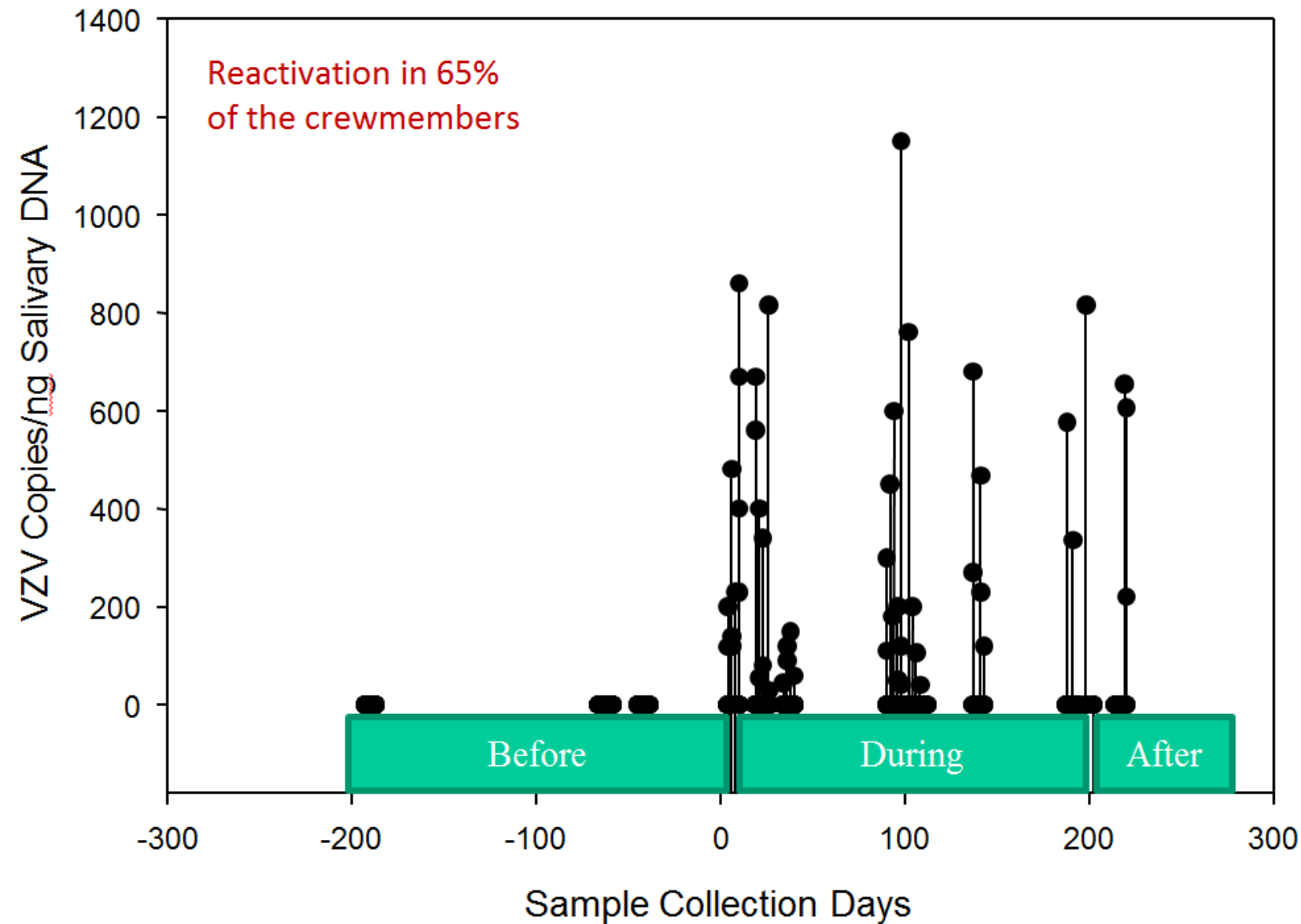




Resistive Exercise Device



Reactivation of Varicella Zoster Virus(VZV) in Astronauts



Potential Immunologic Countermeasures for Deep Space Missions

Precision Countermeasures

Pre-Mission Immunological Screen

Pre-mission immunological screen may include:
Personal history of allergy/hypersensitivity, etc.
Medication history (antihistamines, etc.)
Leukocyte distribution (NK cell subsets)
Cytokine concentration: Th1/Th2, etc.
Allergy screen, patch testing
Latent herpesvirus sero-positivity

Pathogen-Specific Mitigations

Antiviral (VZV) vaccination



General Countermeasures

Already in Place/Will be Optimized

Pre-flight medical operations screening of crewmembers
Pre-flight quarantine
Microbial screening of vehicle/payloads/foods
Environmental control
Optimized exercise equipment
Radiation shielding

Multisystem Countermeasures

Optimized exercise regimen
Adequate sleep schedules
Psychological support - family communication
Stress relieving techniques



Specific Countermeasures

Nutritional Countermeasures

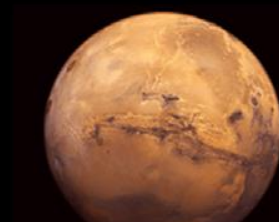
Diet optimized to reduce nutrient deficiency
Functional foods/bioactive compounds
Nutritional supplements:

- Antioxidants
- Probiotics
- Omega 3 fatty acids
- Supplemental nucleotides
- AHCC
- Pegylated-IL-2

Pharmacological Intervention

Beta blockers
Anti-cortisol
Antibiotics
Antiviral
Anti-inflammatory
Cytokine therapy

In-flight Monitoring of Immune Parameters?



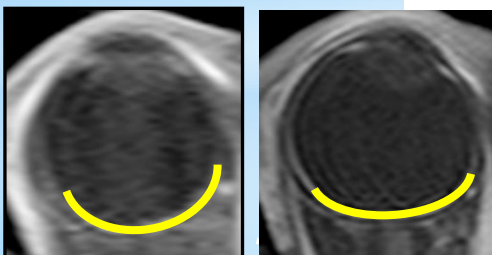
•Hyperopic Shifts

-Up to +1.75 diopters

E	1	20/200
F P	2	20/100
T O Z	3	20/70
L P E D	4	20/50
P E C F D	5	20/40
E D F C Z P	6	20/30
FELOPZD	7	20/25
DEFPOTEC	8	20/20
LEFOPFOY	9	
PZPLTCNO	10	
YARALFTT	11	



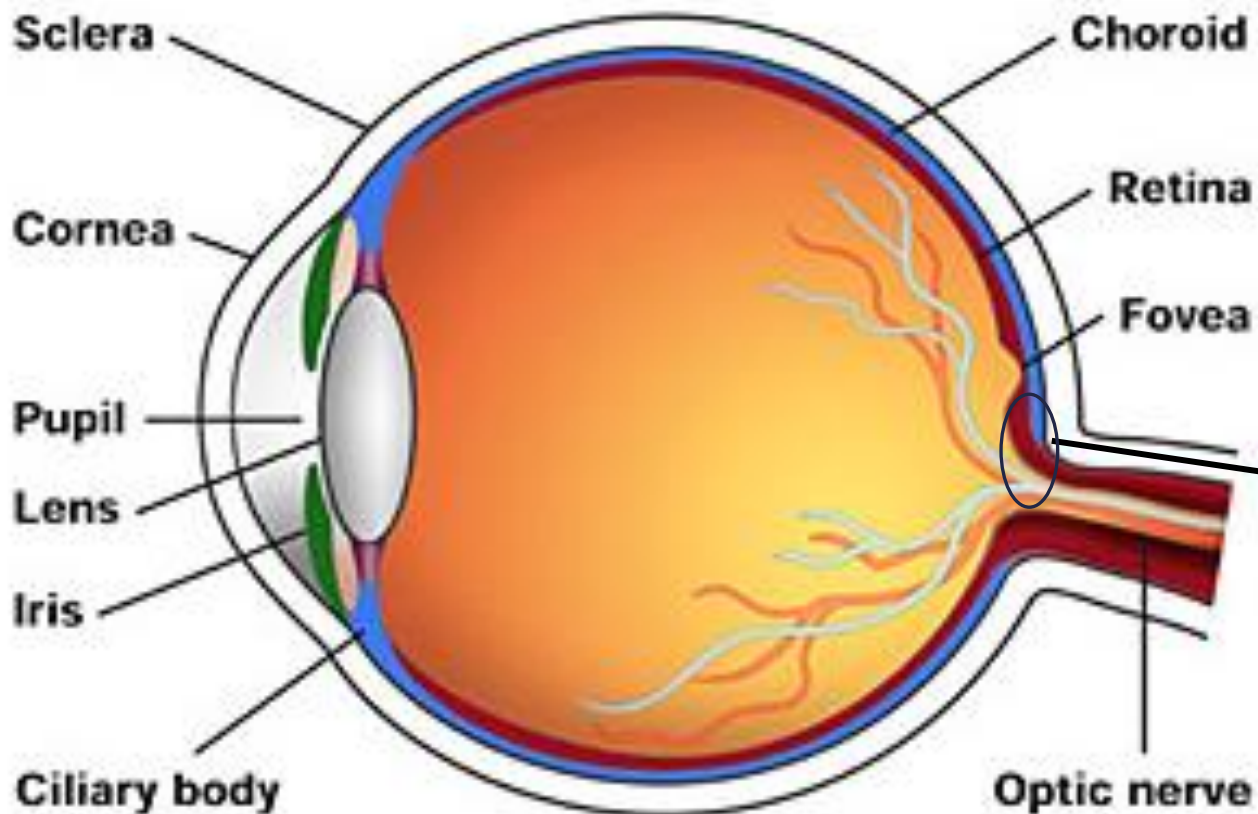
•Globe Flattening



Normal Globe Flatten Globe

MRI Orbital Image showing globe flattening

Macias, JAMA Ophthalmology, 2020

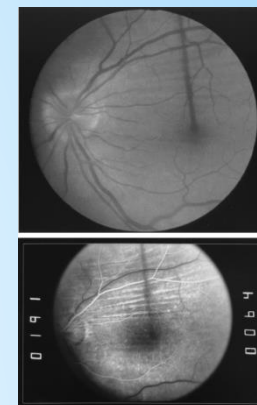


•Altered Blood flow

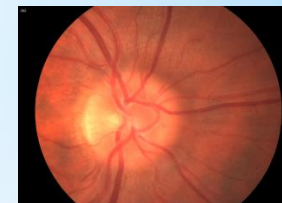
•“cotton wool” spots



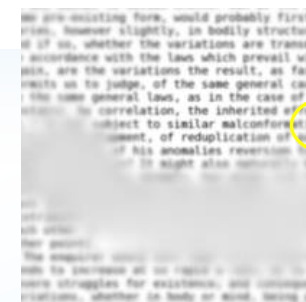
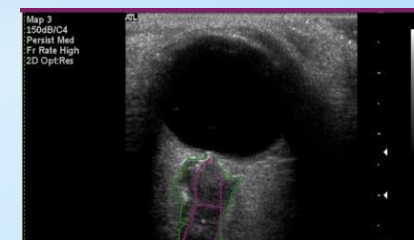
•Choroidal Folds - parallel grooves in the posterior pole



•Optic Disc Edema (swelling)



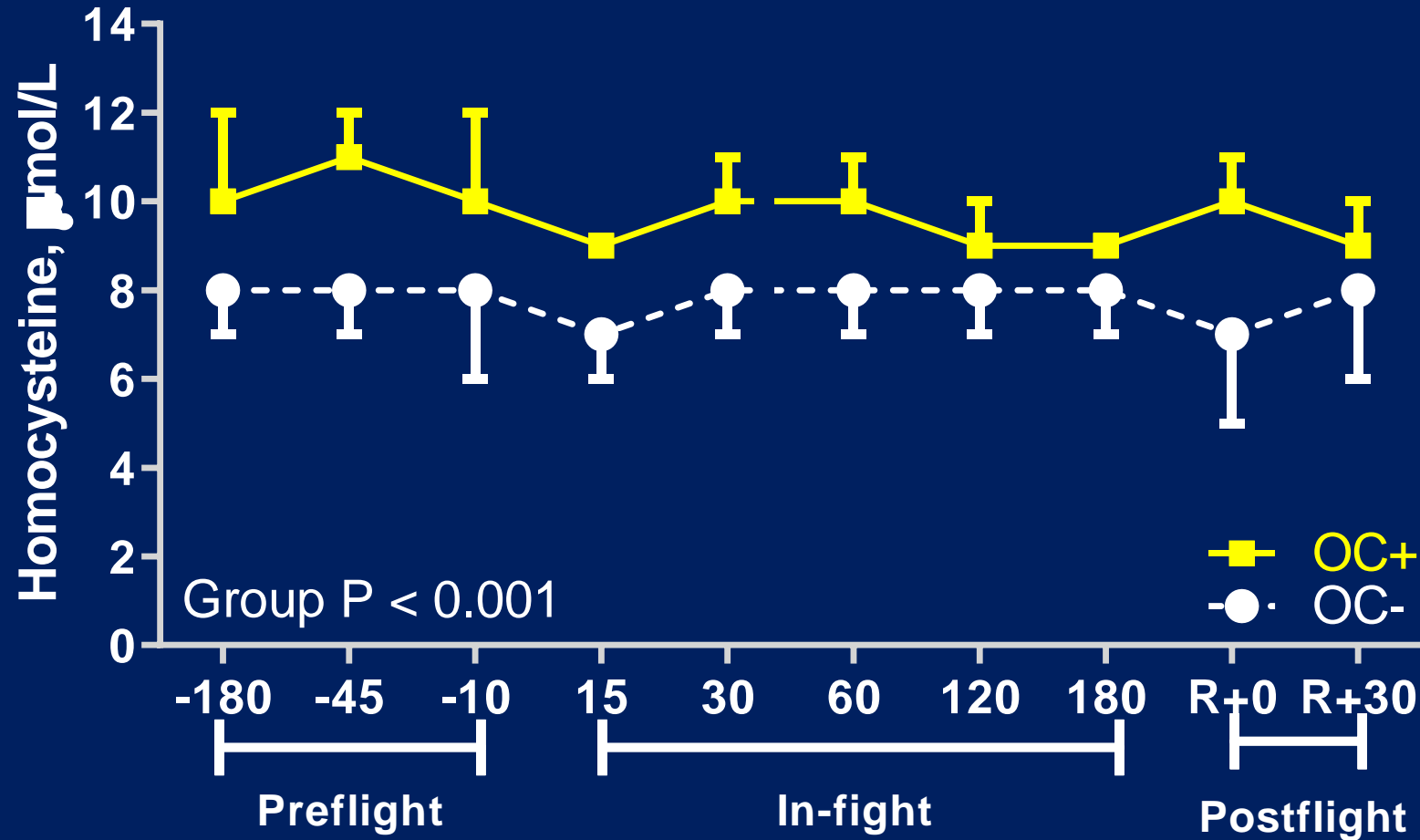
•Increased Optic Nerve Sheath Diameter





Addressing Critical Health Issues for Exploration- ISS research is necessary to address a recently discovered health issue related to long duration space exposure. As a result of elevated intracranial pressure in space, visual acuity changes are occurring in over 76% of astronauts.

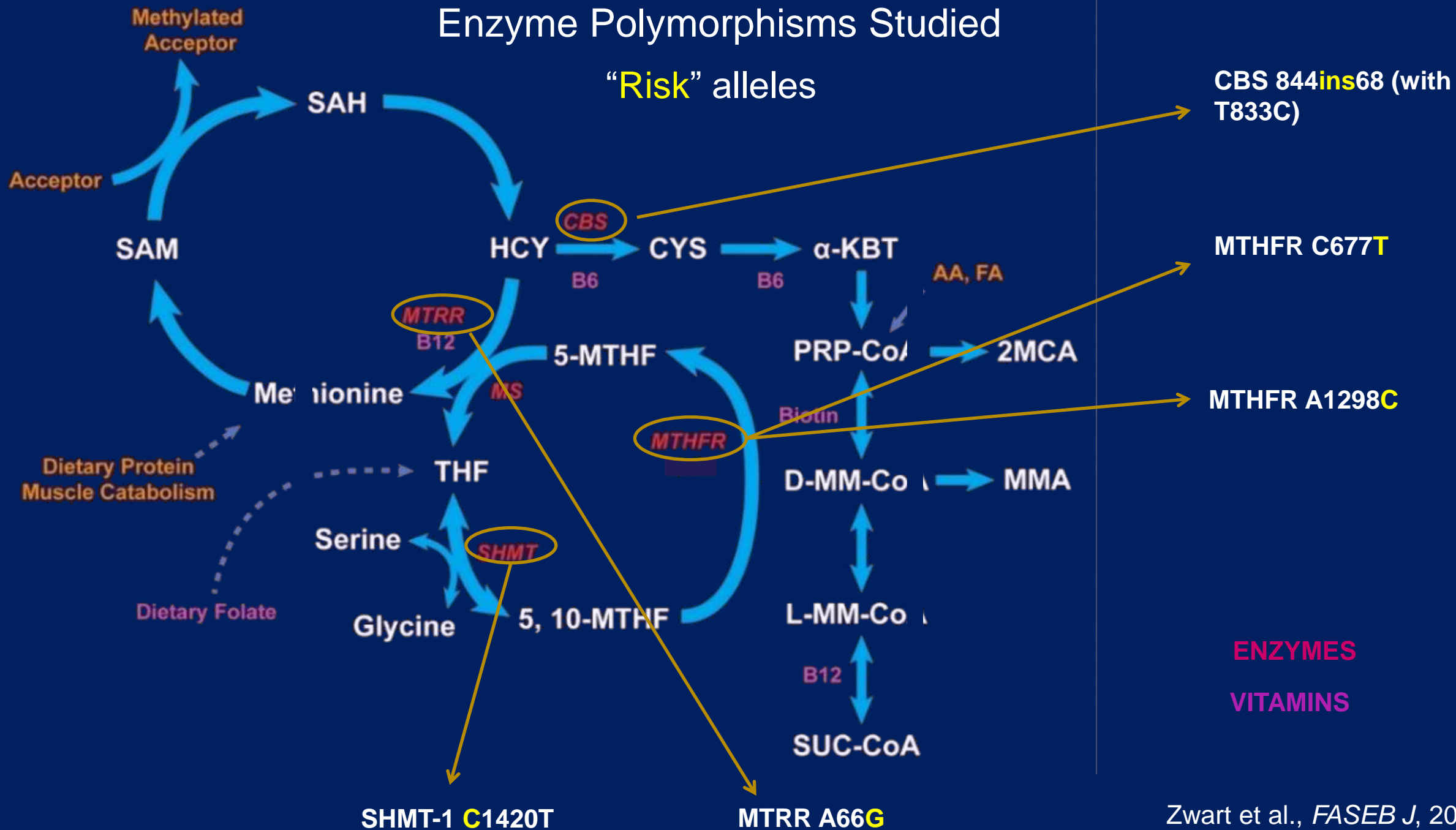
Astronauts **with ocular changes** had higher serum homocysteine concentration than astronauts without ocular changes. **Before** flight.



Zwart et al., Vision changes after spaceflight are related to alterations in folate- and vitamin B-12-dependent one-carbon metabolism.. *J Nutrition*, 2012

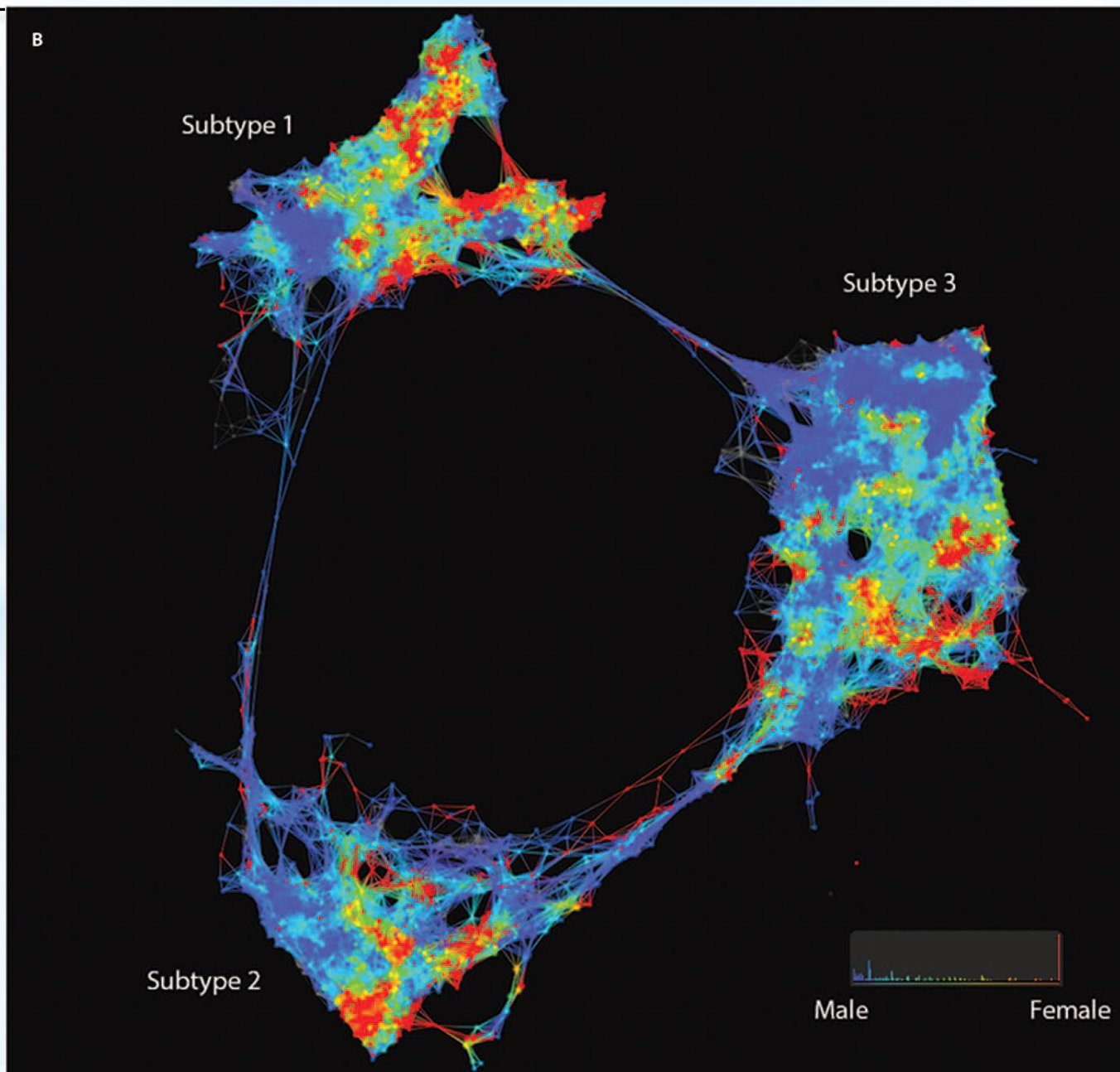
Enzyme Polymorphisms Studied

“Risk” alleles



Type 2 Diabetic Patients
N = 1184

Subtype 1 : Kidney and Eye
Subtype 2 : Heart and cancer
Subtype 3 : Heart and Neuro

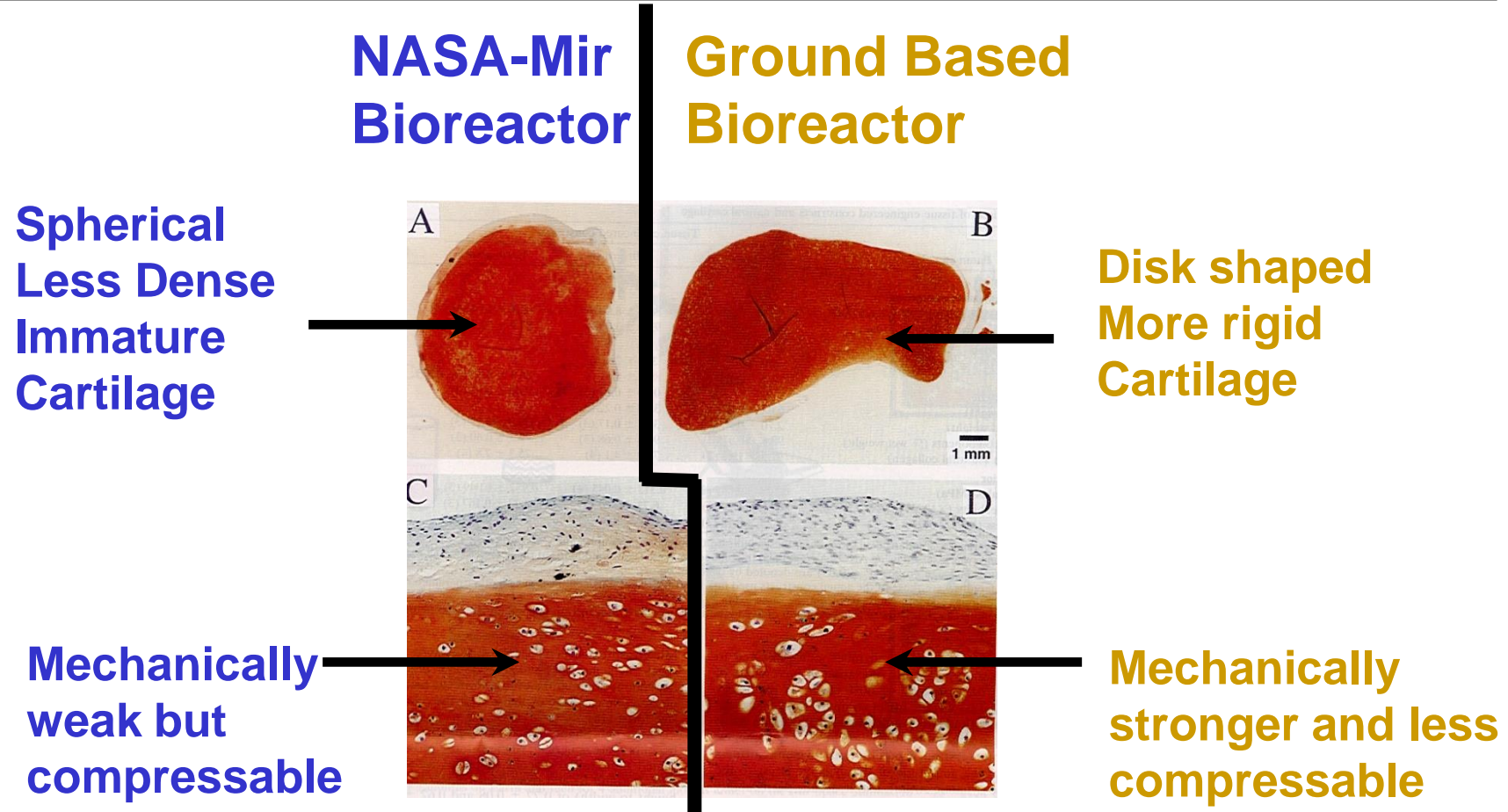


System Biology

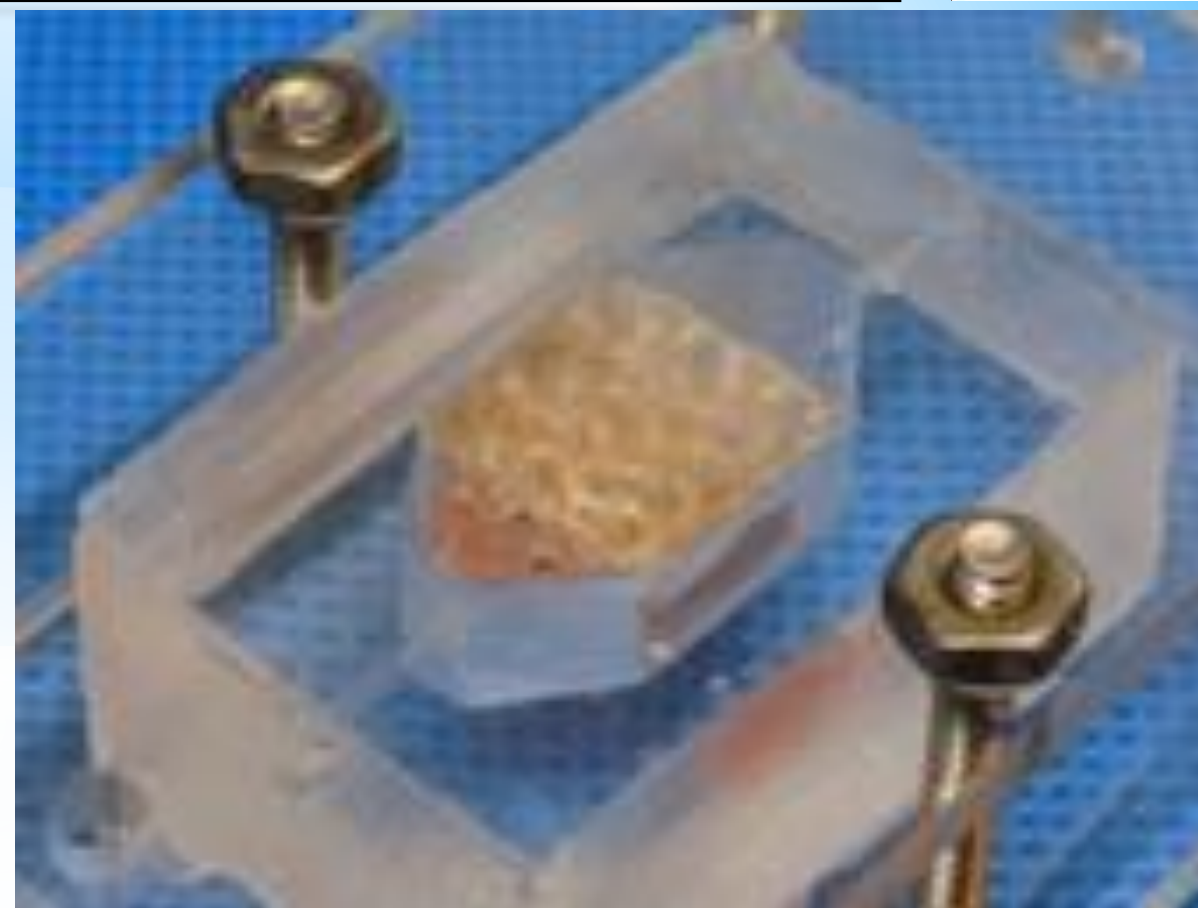
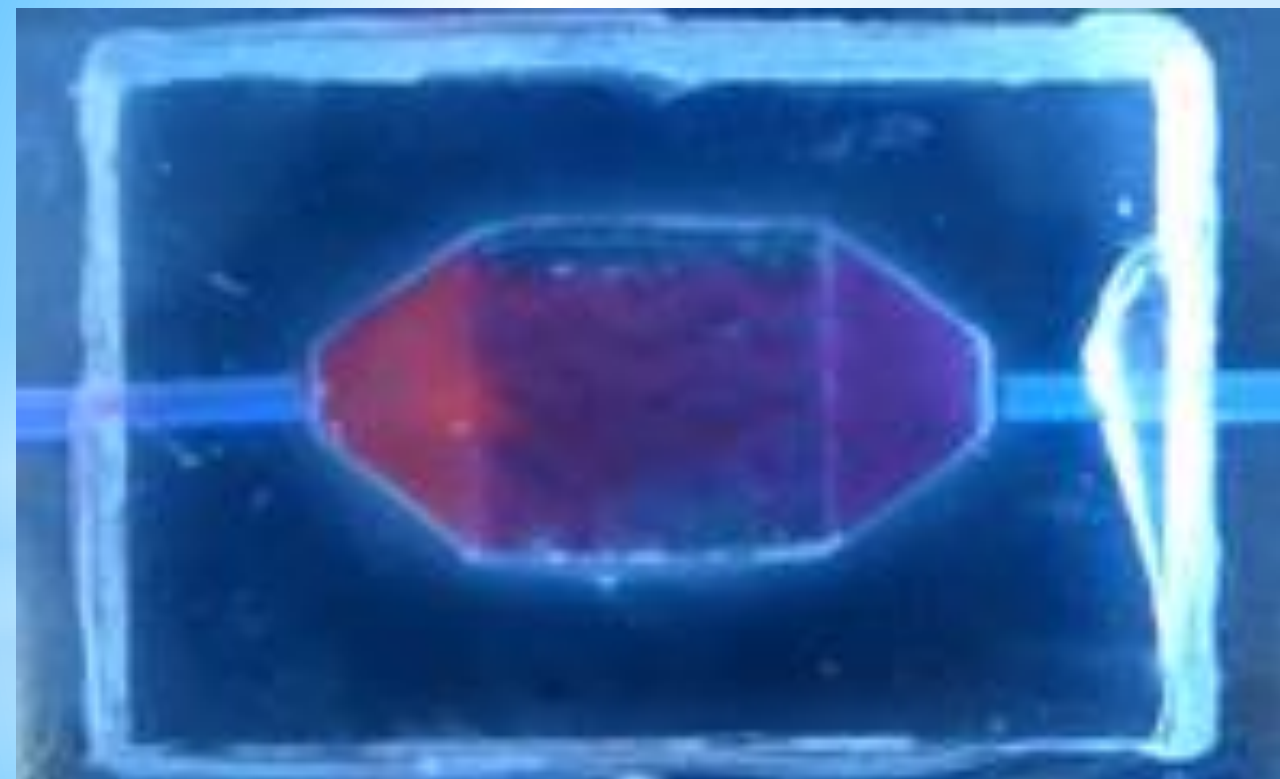


The Cellular Biotechnology Program

Johnson Space Center Houston, Texas

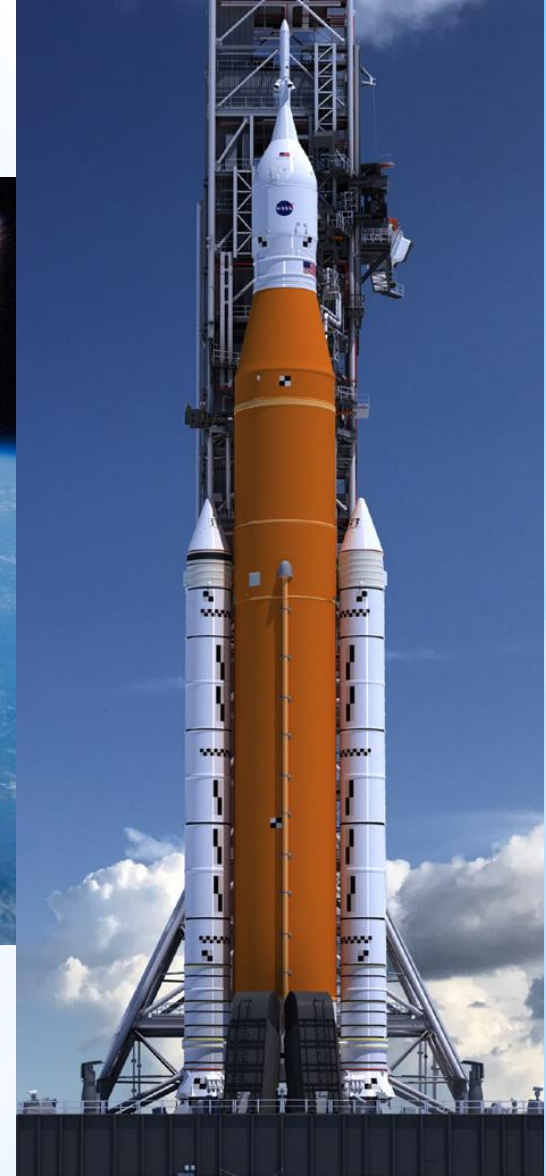
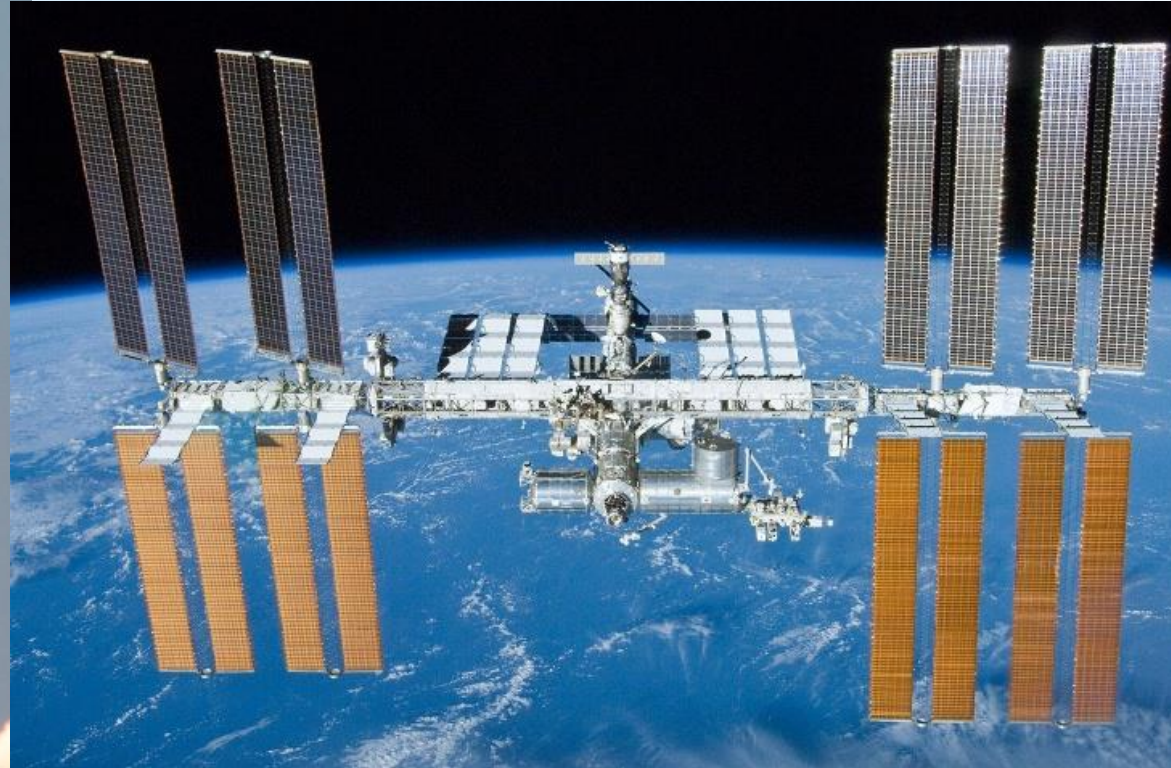
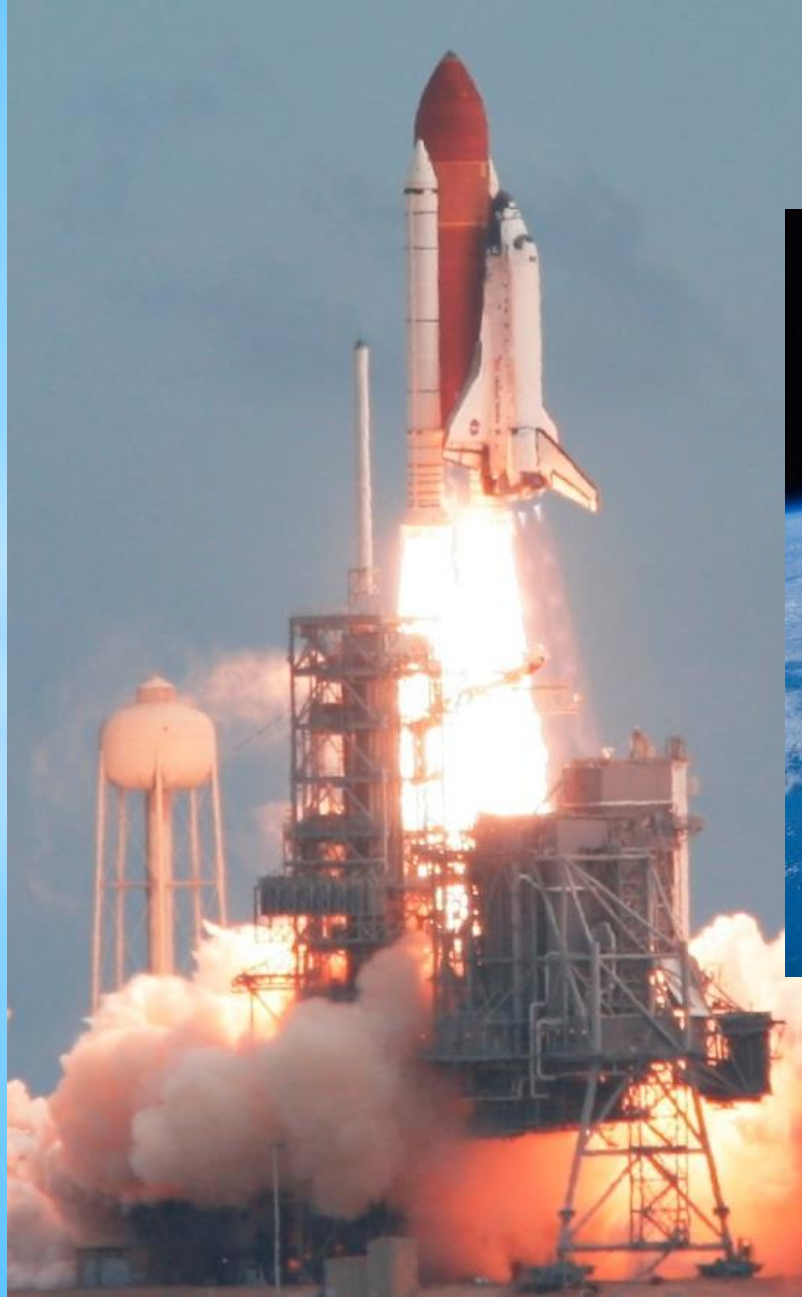


PI : Dr. Lisa Freed, MIT, *Proc. Natl. Acad. Sci.* 94, (1997) pp 1385-1389.



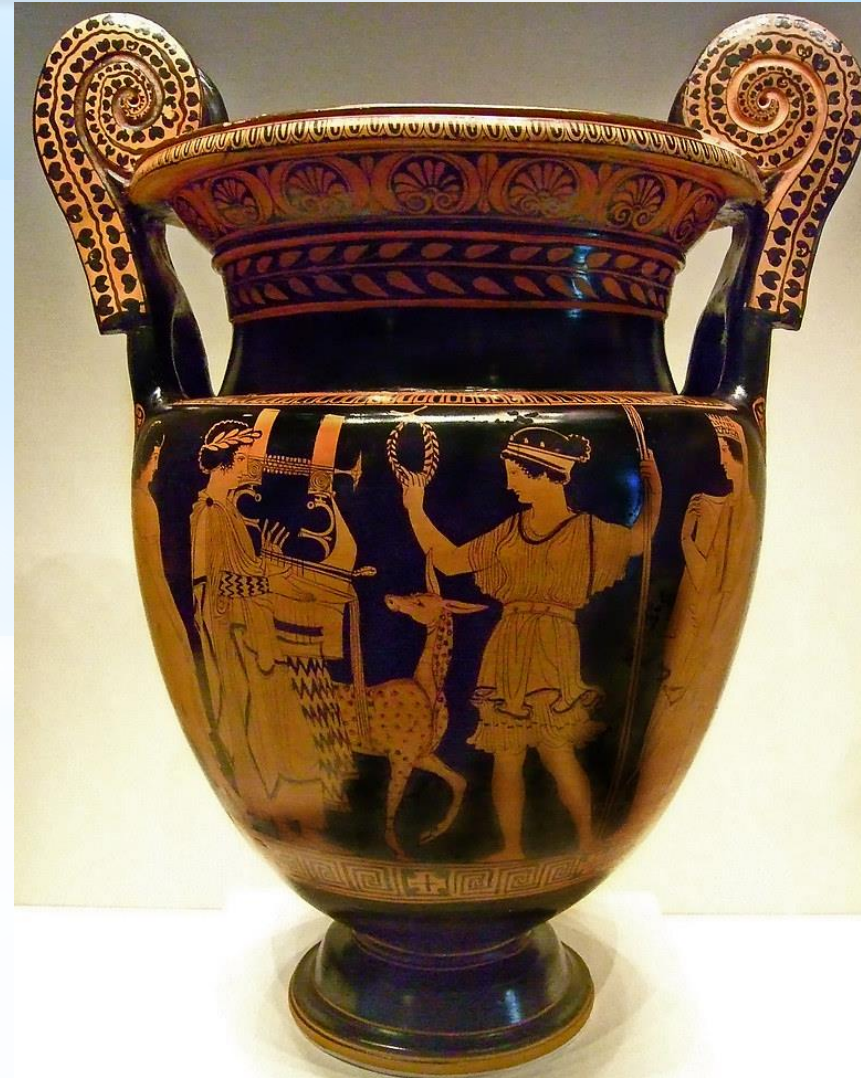
Vascularized Human Liver Tissue (1 cm³; 30 day Survival)
Wake Forest Institute for Regenerative Medicine, NC

System Engineering (Past, Present and Future)





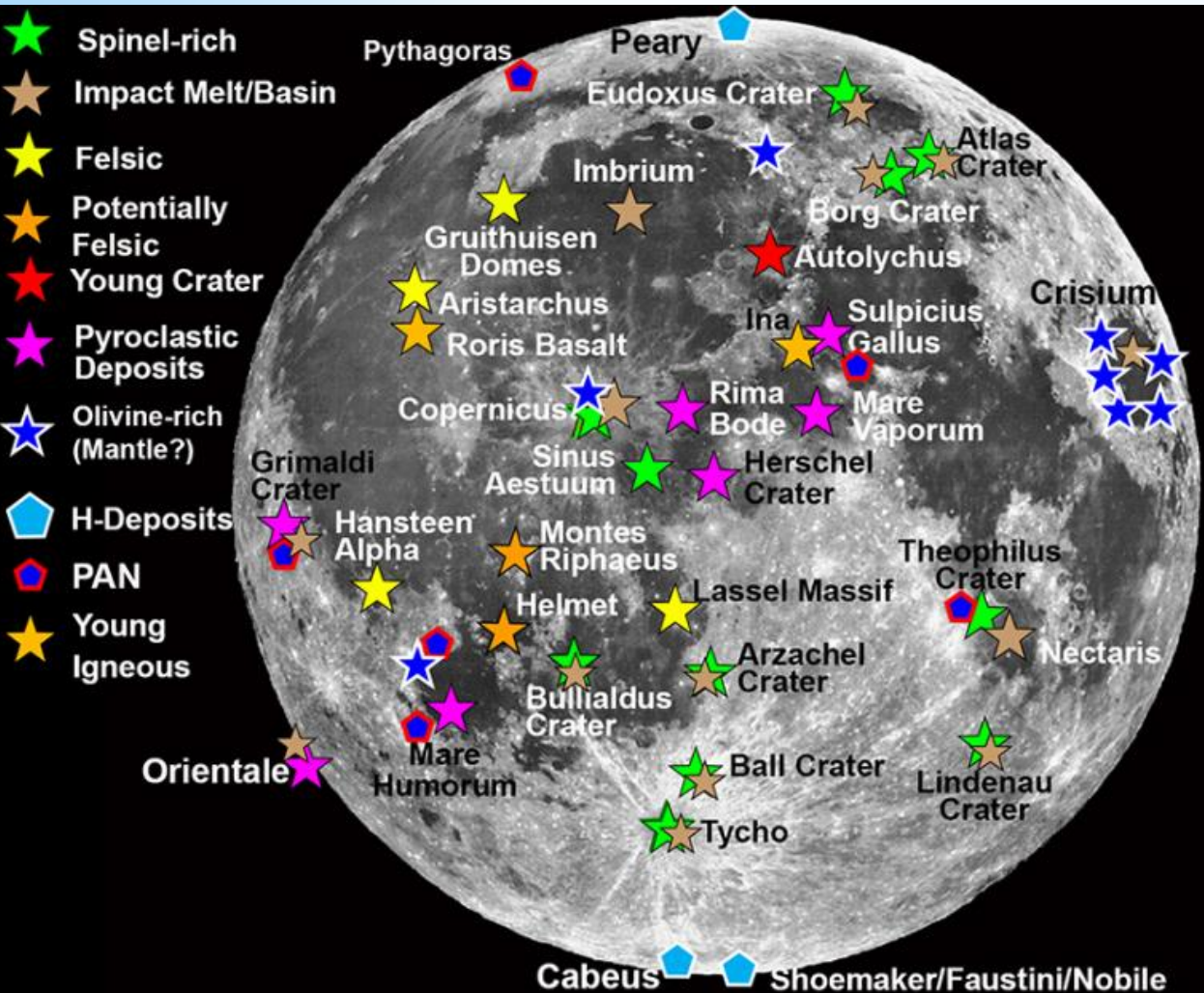
First woman to land on the Moon
Technology validation on Moon for the Human
Space Exploration of Mars



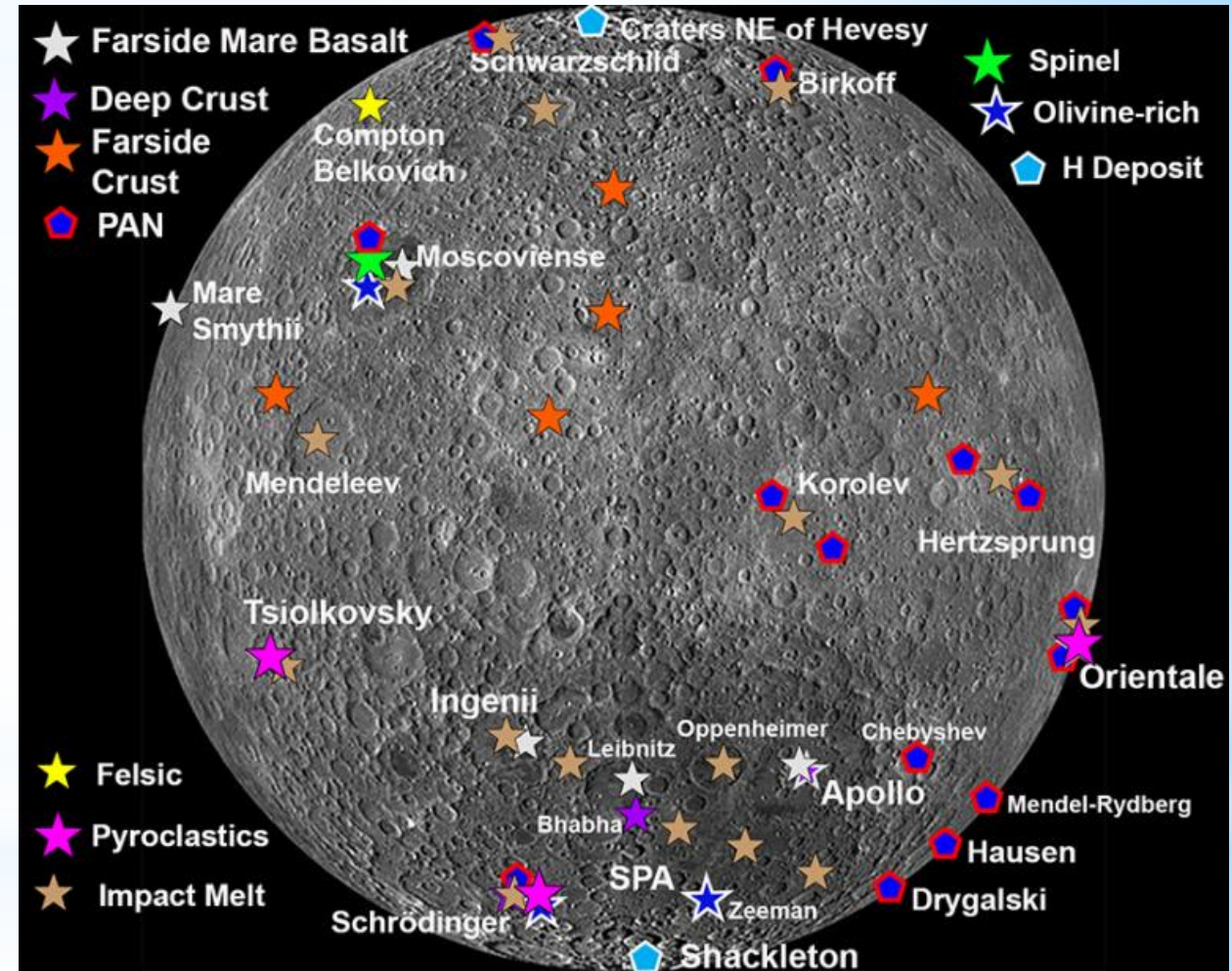
In Greek Mythology, Artemis is the
twin sister of Apollo₅₇

Lunar Scientists have a lot of places they would like to go!

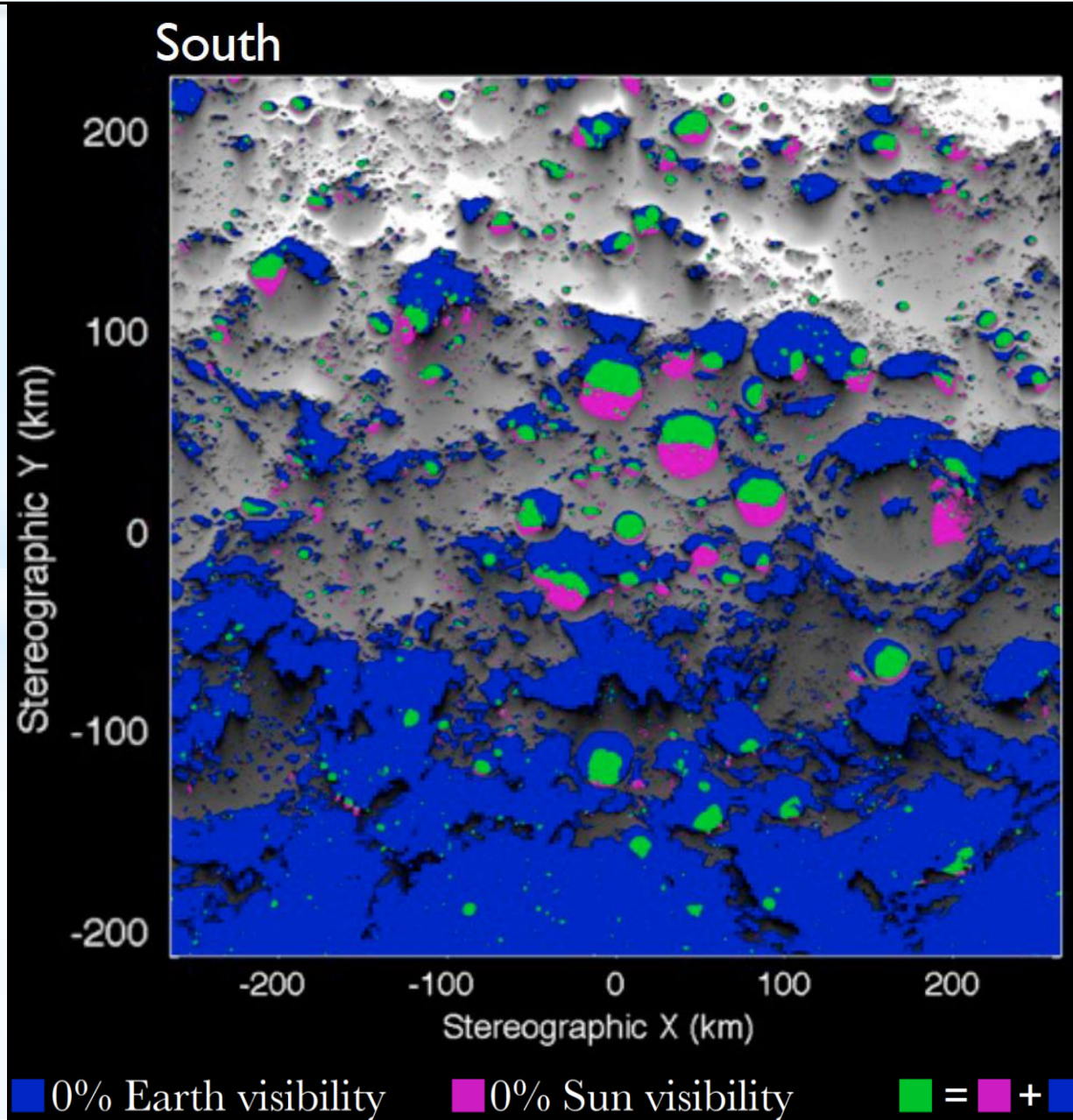
(<https://lunar-landing.arc.nasa.gov/>)



Near Side



Far Side



Mazarico, LEAG 2013



To become an Astronaut?



- Training in one of the STEM (Science, Technology, Engineering and Mathematics) disciplines
- Diverse Experience
- Team Player

- Group Living Skills
- Teamwork Skills
- Performance under Stress
- Self-regulation
- Motivation
- Judgment/Decision-making
- Conscientiousness
- Communication Skills
- Leadership/Followership Skills

Astronaut Class of 2021

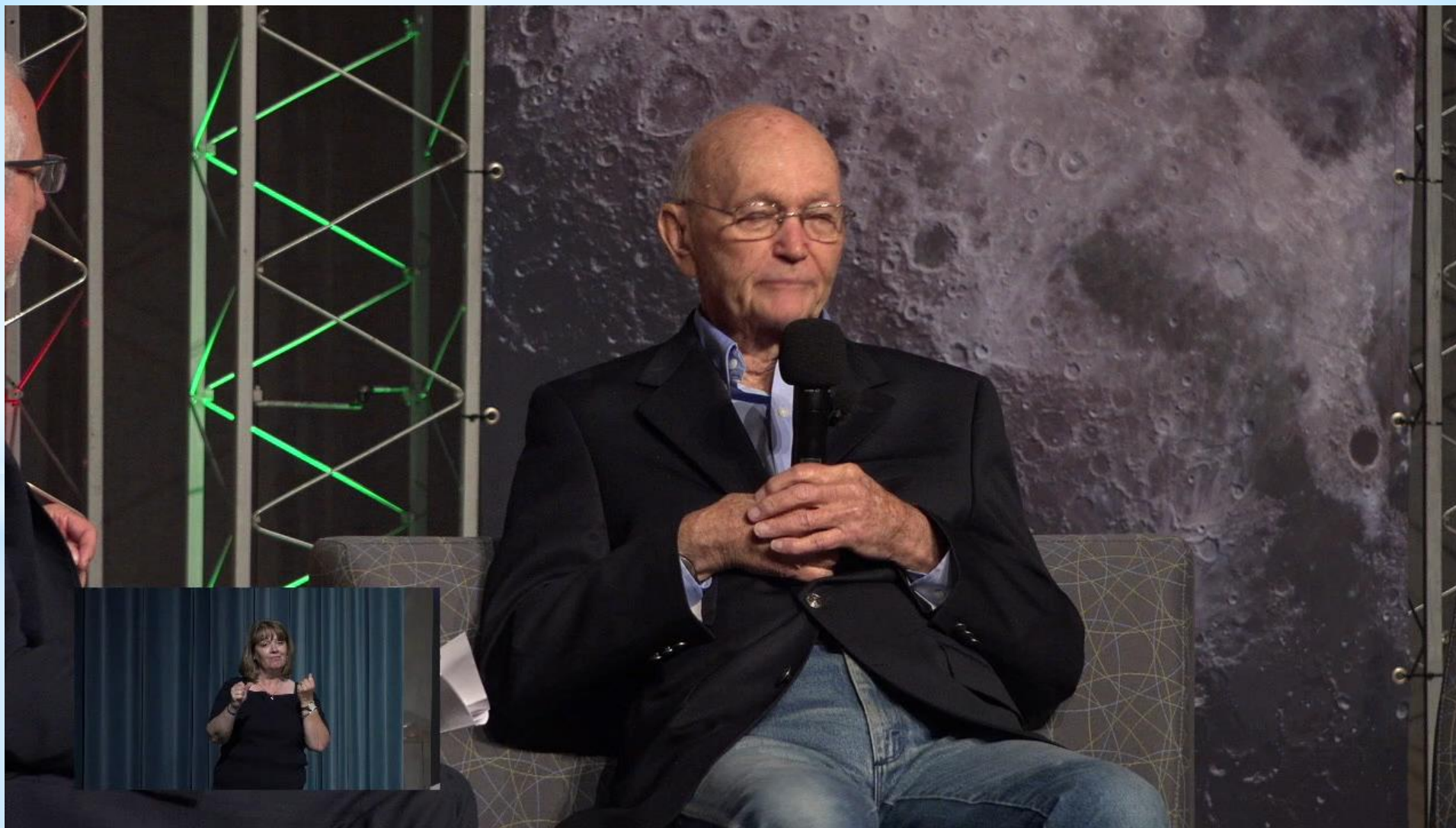


U.S. Air Force Maj. Nichole Ayers, Christopher Williams, U.S. Marine Corps Maj. (retired) Luke Delaney, U.S. Navy Lt. Cmdr. Jessica Wittner, U.S. Air Force Lt. Col. Anil Menon, U.S. Air Force Maj. Marcos Berríos, U.S. Navy Cmdr. Jack Hathaway, Christina Birch, U.S. Navy Lt. Deniz Burnham, and Andre Douglas. Credits: NASA

Knowledge will travel rapidly to
Individuals, who are
Ready, Capable and Eager to Apply

Needs and Outcome Oriented
Applied and Translational
Socially Responsive & Use-inspired Basic

Who is at Your Window?



I feel responsible - Collins

Acknowledgment

Engineers, Scientists
Physicians and Astronauts

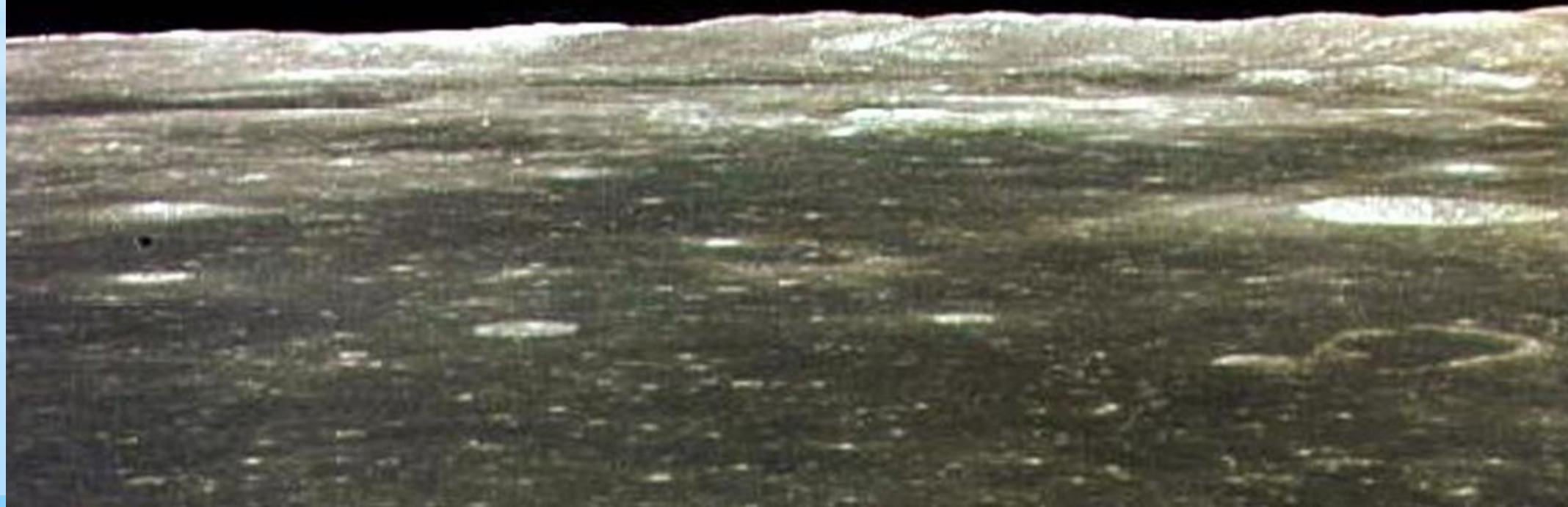
Thanks



Beautiful Fragile Blue Planet



With God's grace, Make a difference
Passion, Perseverance and Patience





BACK-UP





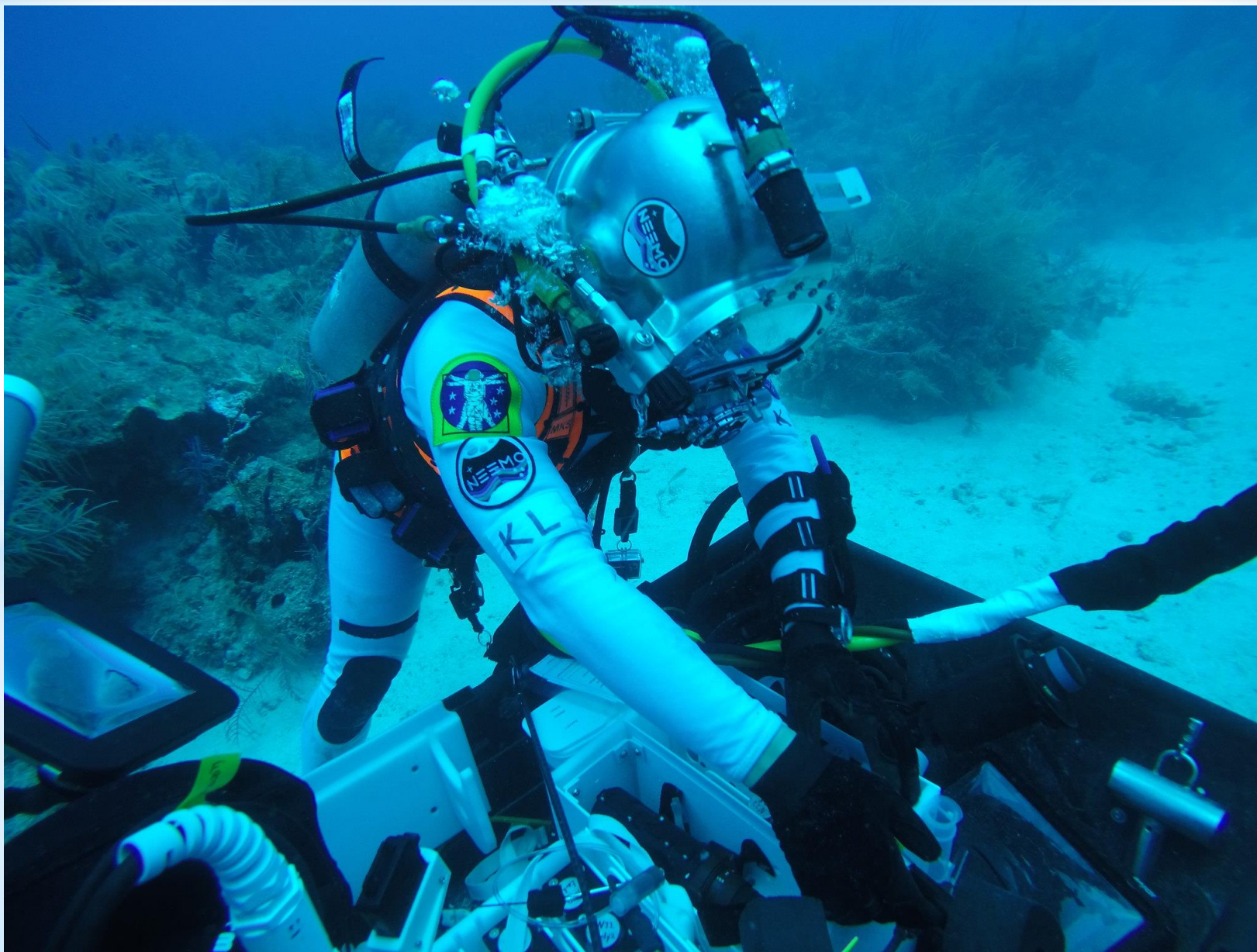
EVA at Neutral Buoyancy Lab (NBL)



Bed Rest Studies :envihab



Under Water NEEMO



Mars 500 Analog



Rover : Desert Rat



Deep Space Habitat : Isolation and Confinement



Zero-Gravity Aircraft





Shuttle Launch : Speed of Rocket



Gross Lift-off weight : 2 Million tons

Thrust : 33,327 kilonewtons

SRB Separation : 45 km

External Tank Separation : 111 km

Orbital velocity : 27,869 km/hour

Payload weight : 25 tons

Shuttle weight : 78 tons

Routes into biologically isolated sections of the Lunar Receiving Lab are shown here by red lines. At upper left, lunar samples arrive and are taken to vacuum system and radiation lab by elevator. Other entrances indicated are for astronaut, for the command module, for food and laundry. Lines at far right show where lab personnel come and go through ultraviolet airlocks (purple).

Lunar Sample Laboratory

More than 300 scientists and technicians will perform tests with lunar materials in the lab area, shaded green.

- 1 Vacuum system where lunar material is received and processed
- 2 Corridor for storage and transfer of lunar material
- 3 Corridors for vacuum system
- 4 Equipment for postflight food sterilization
- 5 Gas analysis laboratory
- 6 Special air conditioning system to sterilize air entering and leaving building
- 7 Elevator
- 8 Viewing room for participating scientists
- 9 Pump room and electrical support equipment for vacuum system
- 10 Transfer tubes for moving samples directly from vacuum system to lab
- 11 Physical chemical test lab—mineralogy, petrology, geochemistry
- 12 Bio-preparation lab where lunar material is prepared, weighed and packaged for distribution
- 13 Bio-analysis lab for blood tests and other tests on mice
- 14 Holding lab for germ-free mice
- 15 Holding lab for conventional mice
- 16 Lunar microbiology lab to isolate, identify and possibly grow lunar microorganisms
- 17 Spectrographic lab and darkroom (connects to 11)
- 18 Bird, fish and invertebrate lab where shrimp, quail, cockroaches, oysters and other creatures are exposed to lunar material
- 19 Microbiology lab for test cultures of lunar and astronaut material
- 20 Egg and tissue culture lab (support and additional facilities for 21)
- 21 Crew virology lab for postflight virological analysis of astronauts
- 22 Plant lab where green-free algae, spores, seeds and seedlings will be exposed to lunar material
- 23 Entrance to lunar sample operations area. Showers and facilities for all personnel passing in and out to change clothing
- 24 Autoclave for sterilizing all material entering or leaving area
- 25 Bio-safety lab to monitor all systems
- 26 Support offices
- 27 Entrance to radiation counting lab

Anatomy of a Lunar Receiving Lab

Astronaut Reception Area

Quarantine area where astronauts will live and be examined is shaded yellow. In an emergency, lunar lab workers could also be quarantined there.

- 1 Crew reception area connected to transfer van
- 2 Medical and dental examination room
- 3 Medical examination room
- 4 Operating room
- 5 Life-table room for physiological testing
- 6 Tape-out room where data can be passed into nonquarantine area electronically
- 7 Biomedical lab—clinical chemistry and immunology of astronauts and support personnel
- 8 Exercise room
- 9 Astronaut debriefing room, separated by glass from family visiting room
- 10 Dormitory for support personnel

Radiation Laboratory

Chips from the first lunar samples will be sent to a radiation lab (blue in drawing) built 50 feet underground. There, their radioactivity will be measured and results may help indicate the age of the rocks and whether they ever existed in molten form.

Support and Administration

Beyond the two biologically secure portions of the lab, offices and support facilities are shown at left above by the light green area; test animals and plants are raised and watched for studies. When quarantine is lifted, other areas in the section will be used to prepare lunar samples for shipment to universities around the world.

Astronaut Class of 2017



Zena Cardman, Jasmin Moghbeli, Jonny Kim, Frank Rubio, Matthew Dominick, Warren Hoburg, Robb Kulin, Kayla Barron, Bob Hines, Raj Chari, Loral O' Hara and Jessica Watkins.



Magnitude of the Universe

Number of Atoms in the Universe $< 10^{80}$

Atoms in the earth = $6 \times 10^{27} \text{ g} / 12 \text{ g}) \times 6 \times 10^{23} = 3 \times 10^{50}$

Atoms in the solar system = $3 \times 10^{50} \times 1000 = 3 \times 10^{53}$

Atoms in the Milkyway Galaxy = $3 \times 10^{53} \times 10^9 = 3 \times 10^{62}$

Atoms in the Universe = $3 \times 10^{62} \times 10^9 = 3 \times 10^{71}$



View from Sudan





Zuma Pilot Picture



Why Mars?

- * Mars is our most hospitable planetary neighbor
 - * Venus is closer, but its average temperature of 462°C (864°F) and the sulfuric acid atmosphere—90 times higher pressure than Earth—would crush our spaceships
- * Mars will feel like home in many ways:
 - * Approximately the same day/night cycle as Earth
 - * 4 seasons: cold winters, but as warm as 20°C (70°F) on a summer day
 - * Vistas similar to Earth's deserts: mountains, cliffs, valleys, dunes, dust devils
 - * Abundant natural resources: oxygen (from ice or CO₂), water, iron, sunlight
 - * Enough atmosphere to provide some radiation protection
- * Mars is also exotic:
 - * 0.64 of Earth's gravity and 2 moons that cross each other traveling different directions
 - * May have once supported life
 - * We don't know what may be underground--our rovers have only explored a fraction of Mars' surface



5.02 - 30.74 kg per person-day

DAILY INPUTS - NOMINAL

	kg
Oxygen	0.84
Food Solids	0.62
Water in Food	1.15
Food Prep Water	0.79
Drink	1.62
Hand/Face Wash	
Water	1.82
Shower Water	5.45
Clothes Wash Water	12.50
Dish Wash Water	5.45
Flush Water	0.50
TOTAL	30.74



Resources and Recycling

- Water Regeneration Reactors
- Air Revitalization Reactors
- Environmental Sensors (Chemical)
- Microbial Monitors

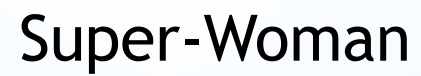
11.3 Metric Tons Per Person-Year

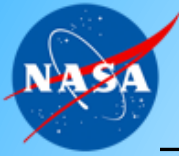
DAILY OUTPUTS - NOMINAL

	kg
Carbon Dioxide	1.00
Respiration and Perspiration Water	2.28
Urine	1.50
Feces Water	0.09
Sweat Solids	0.02
Urine Solids	0.06
Feces Solids	0.03
Hygiene Water	6.68
Clothes Wash Water	11.90
Clothes Wash	0.60
Latent Water	
Other Latent Water	0.65
Dish Wash Water	5.43
Flush Water	0.50
TOTAL	30.74

Salt and Pepper







One Day in other planets



Planet	Day Length
Mercury	1,408 hours
Venus	5,832 hours
Earth	24 hours
Mars	25 hours
Jupiter	10 hours
Saturn	11 hours
Uranus	17 hours
Neptune	16 hours

